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FACTORY PRODUCTIVITY AND EFFICIENCY

II. DESIGN AND MATERIAL USAGE

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This article is the second in the series reporting on the result of a detailed comparative study, made possible by financial help from the Board of Trade and the Department of Scientific and Industrial Research, of three factories in the fractional horse-power electric motor industry. All data used in this article relate to 1954 *or earlier years. Designs and markets have changed since then, and it is not to be supposed that comparisons of material usage in* 1961 *would yield similar results. A general account of the aims of the study—and of the comparative techniques used—was given in* The Bulletin, *Vol.* 22, *August* 1960.

We again wish to thank the firms, their managers, and their staffs for their unstinted co-operation. Naturally they bear no responsibility for the content of this article. The factories will be referred to by the initials B, C, and D.

The three factories produced a large number of different motors to serve a variety of uses in industry and in the home. A central problem, both in design and in manufacturing, was to reconcile the production of a mixed output with economy in the usage of resources. It is logical to consider the design solutions first, since they in large measure determine the form and content of the manufacturing problem. More directly, the design solutions determined the usage of materials; and in this article we shall compare the usage of direct materials[1] necessitated by the designs adopted. The importance of such a comparison is indicated by the fact that the material bill in these factories was 4–5 times the direct labour bill, and accounted for 55–60 per cent of total manufacturing cost. It is also in some ways the easiest comparison to make—as noted in the first article of this series, there was a greater degree of detailed consistency and comparability in the data for material usage than was found for other inputs.

Motor design is necessarily a technical subject. In what follows, technical detail is reduced to a minimum; partly for the very good reason that we do not pretend to be technical experts. It is no part of our intention to assess how good or how bad a design may have been. If it had been the case that all design problems were purely technical problems, this article could never have been written. We begin by describing how motors were constructed in order to provide the background against which the broader implications of differing design decisions can be considered.

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[1] *I.e.* materials incorporated into finished products.

Motor Design and the Range of Output

Fractional horse-power induction motors are simple machines for converting electrical energy into mechanical energy. Those produced in these factories have four major components—a stator, a rotor, and two endshields. The stator and the rotor form the electrical core; the endshields are structural parts necessary to protect the core and to hold the motor together. In addition a mounting (some means of fixing the motor to the machine it is to power) is often attached by the manufacturer;[1] and there is a large number of minor parts and assemblies—terminals, switch, nameplate, lead wires, fixing bolts and so on. The *stator* has an outer protective covering of steel or aluminium, within which is fixed a stack of annular laminations, stamped out of thin strips of high-quality electrical steel. Slots in the laminations contain the stator windings, which consist of numerous coils of copper wire. The *rotor* is built up from a stack of circular electrical laminations, which has after machining a fractionally smaller diameter than the internal diameter of the annular stator stack. The rotor laminations, too, are slotted; the ‘ windings ’ normally consist of channels of aluminium short-circuited by an aluminium ring at both ends. The steel shaft passes through the centre of the rotor stack and protrudes from each end. The *endshields* are cast in aluminium or iron, and are fitted to each end of the stator. The electricity supply is fed into the stator windings, which are so arranged that the fluctuating magnetic fields set up by the alternating current cause the rotor and its shaft to revolve inside the stator. The shaft turns in bearings (usually sleeve, sometimes ball) housed in each endshield, and protrudes through one endshield (or occasionally both endshields) to provide the mechanical drive.

Motors can be constructed to operate on various electrical inputs, and to offer a wide variety of output characteristics. The particular combination of input and output characteristics required by a customer will be determined by the use which he intends to make of the motor. To cater for uses requiring different mechanical or electrical characteristics it is usually necessary to produce different motors. A motor built to work on a single-phase electricity supply will not work on the three-phase supply common in industry: the arrangement of the coils of copper wire in the stator is totally different. A ¼ h.p. motor cannot deliver ½ h.p., and to use a ½ h.p. motor when only a ⅛ h.p. was required would entail a gross waste of materials. If a factory decides to cater for a wide range of uses, it has to produce many different motors: but opportunities for component standardisation are considerable.

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[1] For simplicity, mountings have been omitted from this study.

Thus, the same rotor and stator can be incorporated in motors which fulfil different uses because the endshields are different. Or again, motors can be adapted to work on a different voltage by altering the details of the stator windings, leaving the rest of the motor unchanged. In general, most structural variations will not require variations in the main electrical components, and most electrical variations will not require variations in the main structural components. Even variations in the power offered are not incompatible with some measure of component standardisation. More power requires more copper wire, and more electrical steel in the stator and the rotor. The obvious way to increase the amount of steel in the stator and rotor is to add to the number of laminations in the stator and rotor stacks. By this means, the laminations remain the same for different powers; and since the outer diameter of the stator laminations does not change, the dimensions of all the structural components which depend on this diameter—principally the endshields—need not be changed.

All factories exploit these opportunities for component standardisation. The range of motors offering different electrical and mechanical characteristics which are produced with the same external diameter, and with much common use of components, can be regarded as adaptations of a basic design. This brings us to the first fundamental difference between the three factories. In two of them, B and C, all motors[1] produced were adaptations of a single basic design: D produced adaptations of no fewer than five basic designs.

Single basic design production: B and C

It is a consequence of the decision to confine production to adaptations of a single basic design that there are limits to the range of characteristics that can be offered. In particular, the range of power that can be covered by motors of the same external diameter is limited. The limits are not precise, nor are they purely technological; but both factories took much the same decision on what variation in the length of electrical cores (i.e. the length of the rotor and stator stacks) was appropriate. In one, the longest core was twice the length of the shortest, and in the other, 2¼ times. Since the outer diameters chosen were also much the same, it follows that motors from these factories catered for a very similar range of power output—roughly from ⅙ to ½ h.p.[2] Uses requiring powers outside this range could not be catered for by the factories; the decision to standardise by producing a single basic design implied a decision to restrict the range of uses that could be catered for.

Standardisation could have been pressed further, by confining production to a few selected adaptations of the basic design. In fact, both factories chose to exploit the potentialities of design adaptation and cater for a wide range of uses within the limited power range. Most adaptations of individual com-

[1] *I.e.* all motors considered in this study. At each factory other sorts of motors, and some other products, were produced to markedly different designs.

[2] This is the range for the commonest electrical type of motor. For some other types, the same variations in core length correspond to different ranges of power. To avoid unnecessary complications, all horse-powers quoted in this section will relate to the commonest electrical type.

ponents were very straightforward, and a large number of different motors could be produced by ringing the changes on the ways in which the adaptations of individual components were combined in the finished motor. Adaptations of individual components were straightforward partly because the designs were highly adaptable; in effect, the design of components was geared to certain anticipated adaptations. Each of these factories produced a similar 'standard' range of motors, embracing the adaptations envisaged when the main lines of the basic design were decided. Such adaptations were in an important sense 'built into' the basic design: had a very different,or much narrower, set of adaptations been envisaged, the basic design itself would have been different. In addition, motors outside the standard range of anticipated adaptations were produced to special order. Both factories were willing to produce 'specials' which involved comparatively minor adaptations of motors in their standard ranges, but only the prospect of a really large order would induce them to make substantial adaptations to meet the requirements of individual customers.

Essentially, therefore, these two factories took very similar decisions both on the range of uses to be catered for, and on the way to design motors for these uses. The designs were different, but this was mainly because the solutions to design problems were different, and not because the problems to be solved were different.

Multiple basic design production: D

The third factory produced motors of five basic designs. Two basic designs had much the same external diameter as those produced in the other factories, one had a smaller diameter, and two had different larger diameters. No major component (and very few parts) was common between motors of the various diameters: and the two basic designs of the same diameter had no part in common.

With its four different external diameters, this factory was in a position to cater for a wider range of uses than the others. The range of power offered was much wider—from about ⅛ to 1½ h.p. There was some overlapping of power ranges between designs of different diameters: and, partly as a result of this overlapping, the range of power actually catered for by the designs of similar diameter was decidedly narrower than that in the other factories. One of the two basic designs with the same external diameter was a general-purpose design and was (like the designs produced by the other factories) adapted to produce motors for a wide range of uses. The other was a special-purpose design, specifically intended to cater for a narrow range of uses. It could not be adapted to serve most of the uses catered for by a general-purpose design. Before the introduction of the special-purpose design in early 1954, the general-purpose design had catered for the uses taken over by the special-purpose design. It is probable that the decision to introduce a special-purpose design was influenced by the fact that four basic designs were already in production. In such circumstances, the loss of standardisation from the addition of a fifth basic design may not seem as serious as that involved in, say, an increase from one to two basic designs.

The diversity introduced by producing to several basic designs was not offset by restricting the number of adaptations of the designs offered for the standard range of output, or by a greater reluctance to produce to special order. This factory produced a far more varied output than the others, and was more willing to produce special motors involving very substantial adaptations of the basic designs. Indeed, two particular adaptations were so comprehensive that they might be described as separate basic designs. All told, therefore, in this factory considerations of standardisation played less part in the decisions on the range of output to be produced, or on the way to design motors for that range. As a result, it faced a production problem of substantially greater complexity than that faced by the other two factories.

The Technique of Equivalence

The technique of equivalence provides a basis for systematic comparisons of material usage between these three factories.[1] We describe motors from different factories designed to cater for the same use as ' equivalent '. A customer purchasing a motor from the standard range at any factory had to specify at least nine input, output and structural characteristics before the factory could be sure that he should be supplied with one motor, rather than any other motor, from its range of output. Nine characteristics define the most important technical properties of a motor; and any motor described as offering a particular combination of these characteristics should convert a closely specified electrical input into a fairly closely specified mechanical output, and will have certain structural features. These technical properties are normally sufficient to indicate the uses for which a motor is appropriate, but sometimes it is necessary to take note of additional characteristics, particularly in regard to output properties. Thus, if a motor is designed for uses in which an ability to withstand overload is important, the description of the motor usually incorporates some phrase (e.g. ' high-torque ') to indicate its suitability for those uses. The motors we wish to identify as equivalents are those from the three factories which catered for the same uses, usually by offering very similar combinations of technical characteristics.

Though equivalent motors cater for the same uses, it does not follow that any customer would be indifferent between them. He may be able to negotiate better terms at one factory; he may take the view that one of the motors is somewhat better suited to his individual requirements, or that it is more reliable or durable. It is obvious that if *every* characteristic of a motor—technical and non-technical—were taken into account in identifying equivalents, then the only equivalents would be identical motors, and no comparisons between factories producing to different designs would be possible. Substitutability in use is the only criterion which will permit comparisons of design. In a comparison of material usage on equivalent motors, what is attempted is a comparison of the solutions which each factory adopted to the problem of designing motors for the same uses.

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[1] The techniques described in this section will also be used for comparisons of labour usage in the next article in this series.

Such an approach is only practicable to the extent that uses were catered for by very similar combinations of technical characteristics. Equivalents could confidently be identified for the very great majority of motors in the *standard ranges* of output which offered powers from ⅙ to ½ h.p. All these factories produced motors for this range of power, and each offered much the same variations of other characteristics. They all followed the recommendations of the relevant British Standard,[1] and produced motors described as offering ⅙, ¼, ⅓ and ½ h.p. The British Standard lays down certain ***minimum*** performance requirements, and tests on equivalent motors indicated a high degree of similarity in *actual* performance. For most other characteristics, too, equivalents could be identified in a straightforward way from the description of the motors. Motors were fitted with ball or with sleeve bearings: they were designed to work on a three-phase, or on a single-phase, electricity supply. There were, however, minor differences between factories in the specification of input voltages. For example, one covered the range 200/250 volts with three variants, another with two. Fortunately these discrepancies turned out to have trival effects on total material usage.

It would, of course, be too much to expect that equivalents in use could confidently be identified for *all* motors in the standard ranges. The real difficulties are confined to a few motors at the extremes of the ⅙—½ h.p. power range, for which there are grounds for suspecting that the same set of characteristics does not necessarily imply substitutability in use. The most obious examples are sets of characteristics for which the factory with several basic designs would offer motors of a smaller or larger external diameter than those offered by factories producing to a single basic design. For some uses, the difference in diameter will have been unimportant; but for others it may have been of some importance, so that substitutability in every possible use was unlikely. Again, there were a few powerful motors produced by two of the factories for uses in which ability to withstand overload was important. The most powerful motors produced at the third factory did not claim to match the overload performance of these motors. And, finally, there were cases in which it is known that one factory elected to supply a more powerful motor for uses catered for by less powerful motors from the other factories: motors which were effective equivalents in use had substantially different sets of technical characteristics. Problems such as these are intimately bound up with the form of standardisation adopted at each factory, and further discussion is best postponed to a later context. In many industries, where there is not so marked a conformity in the technical characteristics offered, and where uses are less closely definable in terms of technical characteristics, similar problems would seriously inhibit an approach to usage

[1] B.S. 240.

comparisons through equivalence: with the corollary that differences in design could not be handled in any satisfactory way.

For motors *outside the standard ranges*, produced to meet customers' special requirements, equivalent motors were not produced except where customers ordered the same speciality from each of the three factories. But since most special motors involved nothing more than minor adaptations to motors in the standard ranges, it was possible to infer, within narrow margins of error, what material would have been used in the production of equivalent adaptations at the other factories. This procedure could not, however, be applied to two special motors produced by the factory with several basic designs; they involved adaptations so fundamental that any attempt to estimate the material usage on equivalent motors at the other factories would have been highly speculative. We therefore had to exclude these two motors from the scope of the comparative study.

We also had to exclude all motors produced at this factory from its smaller and larger basic designs which offered powers outside the ⅙—½ h.p. range common to all factories. The other factories could not have produced equivalents of these motors without abandoning their decision to confine production to adaptations of a single basic design. Necessarily, this exclusion introduces an element of unfairness into comparisons involving the factory with several basic designs, since its material usage will be assessed in relation to a range of output narrower than is catered for by its designs.

A SINGLE-PRODUCT COMPARISON

Since material usage varies considerably from motor to motor within each factory, the only fair comparison of material usage over a range of output is one which takes into account any difference in the composition of output between factories. Eventually, we shall compare material usage on equivalent outputs, by which is meant outputs which include the same proportion of the various equivalent motors. But it is simpler to begin with a comparison of usage on a single trio of equivalent motors.

In each factory washing-machine motors bulked large in total output, and for our single-product comparison we chose equivalent ¼ h.p. washing-machine motors designed for use on ordinary British electricity supply. At B and C the chosen ' basic ' motor was an adaptation of the single general-purpose design in production. At D the basic motor was a representative of the special-purpose design specifically intended for washing-machine use.

The comparative data available on material usage for these motors are summarised in Table I. The cost relatives have been derived from the cost accounting records at the three factories, and the quantity relatives from design specifications supplemented by measurement of the materials incorporated into the final product. For a variety of reasons, some pairs of physical and cost relatives differ substantially. First, there are ' transfer ' effects, due to the purchase of materials in a more highly manufactured state. D's costs for electrical steel and for endshields refer to the purchase of stamped lamin-

TABLE I

Material Usage for the Basic Motors[1]

(Costs, quantities and usages at factory C=100)

Material	Factory B *Cost*[2]	Factory B *Quantity*[3]	Factory B *'Usage'*[4]	Factory D *Cost*[2]	Factory D *Quantity*[3]	Factory D *'Usage'*[4]
Electrical materials						
Electrical steel (33) ...	105	89	89–95	200	98	98
Copper wire (29) ..	104	114	109–114	101	93	93–97
Electrical aluminium (3)	108	94	94	149	105	105
Total (65)	105	100	98–103	153	96	96–98
Structural materials						
Stator shell (3) ... ..:	360	—	340–380	112	137	120–137
Endshields (11)	111	114	111–114	114	60	57–63
Shaft (3)	85	107	83–87	51	73	49–53
Total (17)	149	—	146–156	100	76	67–74
Miscellaneous materials (18)	171	—	140–146	187	—	135–150
Total, all materials (100) ...	123	—	114–120	149	—	98–103

[1] A ¼ h.p. washing-machine motor at each factory

[2] Costs as shown in cost accounting records.

[3] Physical measures of materials incorporated in final products. Totals are derived using weights computed from C's costs (shown in brackets after the materials).

[4] Ranges within which accurately comparable measures of material usage at similar prices would probably fall. Totals are derived using weights computed from C's costs.

ations[1] and cast endshields: both B and C stamp their own laminations and cast their own endshields. D in effect substituted material costs for labour and overhead costs by transferring work to its suppliers. Since we are concerned with the effect of design on material usage, any cost relatives influenced by such transfers are quite inappropriate. Second, there are differences in the quality of material used, some known to us, and some not. For example, C's design specified the use of a different grade of steel for its shaft, and B's design specified the use of a different type of lamination steel. When there are such differences, a simple quantity relative (e.g. weight of material) is inappropriate. Quantity relatives may also mislead because of detailed inconsistencies or approximations in measurement. On the other hand, cost relatives may mislead because of differences in costing practices, or because different prices were in fact paid for the same material.[2] The 'usage' column of Table I shows our estimates of the ranges within which accurate and comparable measures of material usage at similar prices would probably fall. In locating the ranges, we have taken a view, based on all information at our disposal, of the accuracy and comparability of both the quantity and the cost relatives, after adjusting the latter for transfer effects and other known sources of incomparability. The usage relatives for individual materials have been combined using cost weights based on C's costs: similar overall relatives are obtained if B's costs are used as weights. Experts familiar with the materials concerned would no doubt be able to produce somewhat more refined comparative measures—though when different materials are used in different ways some indeterminacy is inevitable. For our purposes, the measures to hand will suffice.

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[1] Oddly enough, D did in fact stamp for itself the laminations for the basic motor: but they were *costed* as if they had been bought ready-stamped. This is a straightforward example of the sort of trap which is laid for the unwary in the cost accounts.

[2] Materials may be obtained on favourable terms by placing bulk orders, or regular orders, or orders at times convenient to the supplier. What may be called purchasing efficiency is a subject outside the scope of this article: we are concerned to compare usage of materials necessitated by the designs adopted.

The first conclusion from the table is simple: to the order of accuracy obtainable with data of this kind, one may ignore differences in usage of the electrical materials which account for up to two-thirds of the materials necessitated by the designs.[1] As between B and C, there appears to have been some substitution of one electrical material for another; and although D's usage appears to have been fractionally lower, its special-purpose design permitted no major economies that were not achieved by the other factories with their general-purpose designs. But for the structural and miscellaneous materials, the usage differences were so substantial that the qualifications that have to be made about the figures are of minor importance.

For structural materials the main sources of the differences are not in doubt. B's high usage in relation to C is largely attributable to its decision to make the outer frame of its motor (the stator shell) by die casting aluminium round the steel core. C used the cheaper technique—both in materials and in work to be done[2]—of wrapping sheet steel round the core and welding the join. The use of aluminium offers a number of advantages over the use of sheet steel. It is an easier metal to machine, and so its use speeds up later operations. It does not rust, and so does not require painting—a definite economy on a motor which will not be exposed to view. Even if the motor is painted, it can more easily be supplied in a non-standard colour. A sheet steel shell has to be round, but an aluminium shell may be case to any chosen shape: and the roughly square shape chosen by B permitted the incorporation of certain design features which could improve performance. This shape also differentiated the motors of this factory—a comparative newcomer to the industry—from those of most of its competitors. For most users of motors, questions of appearance can only be secondary; in washing-machines, for example, the motor is tucked away out of sight inside the case of the machine.

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[1] Total material usage comprises the usage of materials necessitated by the designs *plus* material wasted in the production process—the trimmings of materials from which components have been produced, and the materials incorporated into components which have to be scrapped. Material wastage will not be analysed in this article—overall, wastage may account for up to 5 per cent of total material usage. Much of this is associated with faulty materials or faulty workmanship: but for some materials, and notably for electrical steel, the choice of manufacturing technique can substantially affect usage. If our usage comparison had been based, not on material necessitated by the design, but on material necessitated by the design *and* the methods of production used, the electrical steel relative for D in Table I would have been some 20 per cent higher. This is a striking—and quite exceptional—example of the way in which design economy can be offset by a relatively wasteful production technique.

[2] The operations required to make and fix the stator shell took some 70 per cent longer at B than at C.

But for users who intend to expose the motor to view—a common practice in machine tools—both shape and colour could be important. In terms of costs as they stood in 1954, the advantages stemming from the use of aluminium were dearly bought. B's decision to use an aluminium shell had been taken several years previously, when the relative prices of aluminium and steel were more favourable to aluminium, and when there seemed to be some prospect that the relationship would become even more favourable. As it turned out, aluminium prices increased more than steel prices; but the high costs of any design change as fundamental as that involved in altering the shape of the motor led to the continued use of aluminium at a time when its advantages could hardly offset its higher cost. Risks have to be taken when the basic lines of a new design are laid down, and decisions which turn out to be expensive cannot be easily or quickly revised.

At both B and C, some of the structural properties of washing-machine motors were determined by the most stringent requirements of any of the many uses catered for by their general-purpose basic designs. Until early 1954, D's washing-machine motors were adaptations of a general-purpose design which was structurally similar to that produced at C. It then introduced a design specifically for washing-machine motors. Washing-machine duty is not particularly exacting, and in many ways D's special-purpose design could be less sturdy; the shaft was made from thinner bar steel, and less aluminium was used for the thinner endshields. Furthermore, the design did not have to provide for adaptations which would not be required by washing-machine manufacturers. The consequent savings in structural materials are directly attributable to design specialisation: it is a cost of the design standardisation at B and C that structural properties necessary for some uses had to be offered for all uses.

Miscellaneous materials comprise a hundred or so different parts—nuts, bolts, screws, small pressed parts, bits of wire, and so on. D, with its special-purpose design, was able to use some parts which were lighter or cruder than those used at B and C. Yet such savings were offset by its greater usage of other miscellaneous materials, so that in total its usage was little, if anything, lower than B's. And at both B and D, usage of miscellaneous materials was substantially higher than at C.[1] These are materials for which there is considerable scope for economy through ingenuity of design, and through a painstaking attention to detail. Is it possible to dispense with this screw by modifying the design of other parts? Is this sort of bolt really necessary, or would a shorter, or thinner, bolt, perhaps of a cheaper material, be adequate? Not indeed very exciting questions: but the savings can mount up.

It may well be that some of C's economies were associated with its decision to manufacture some parts which other factories purchased from outside suppliers.[1] If parts are purchased ready-made, it will usually be advantageous to buy parts from the supplier's standard range. But if the parts are made in, they can be designed to conform precisely to the factory's requirements. Furthermore, a closer attention to detail in design is more likely if work is done in the factory, if only because a design staff with intimate knowledge of the problems of motor manufacture is on the spot. And finally, there may be further advantages of flexibility if, as is usual, any proposed re-design of one part involves consequential alterations in the design of other parts. However, it may be that the labour and overhead costs of making the parts in the factory are such that any design advantages are dearly bought. On general grounds, it is likely that parts in common industrial use are better purchased from outside suppliers, and that parts specific to a particular motor design are better made in the factory: but it is also likely that a policy of attention to the details of design is more practicable, and more rewarding, if parts are made in.

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[1] Comparisons confined to miscellaneous materials could give a misleading impression of the effectiveness of solutions to design problems. The direct comparison is ' unfair ' to D, in that the use of additional or more expensive parts in its motor could be expected to contribute to economies in other materials or in labour requirements for motor assembly.

For parts made in by all factories, it is notable that C's material economies were associated with lower labour requirements: as in the case of structural materials, lower material usage, far from implying higher usage of other factors of production, was a sign of design decisions taken with an eye to more general economies.

In the comparison between C and D, the former's economies on miscellaneous materials were just about sufficient to offset its greater usage of structural materials. A general-purpose design, adapted for a use in which some excess usage of materials was inevitable, was produced as economically as a special-purpose design. This rather remarkable achievement can more easily be understood in its historical context. C's design in mid-1954 had evolved through a series of modifications to a proved design. Many of these modifications were minor, and some were major; but taken individually none was so far-reaching in its consequences that it could be regarded as tantamount to a re-design of the product. Not long before, a major modification in the design of a set of parts included in miscellaneous materials had almost halved the usage on those parts, and had reduced usage of miscellaneous materials as a whole by no less than 20 per cent. Although the design had been worked on for many years, there was no sign that the economies achievable within that design framework had been exhausted.

Before the introduction of the special-purpose design in early 1954, D's design practices had been very similar to C's. Its general-purpose design from which washing-machine motors were produced had a long history, and had been much modified. But for one reason or another, D had not been able to secure such marked economies in material usage. The motor which it offered for washing-machine duty at the beginning of 1954 used substantially more material than C's motor: most strikingly, the usage of miscellaneous materials was about twice as high. The easiest and quickest way of achieving material economies was to produce a special-purpose design for uses in which the excess usage of materials involved in supplying a motor produced to a general-purpose design was substantial, and which bulked large in total output. Both these conditions were satisfied by washing-machine motors. Total material usage on D's basic motor was some 8 per cent lower than on the general-purpose design motor which it supplied for the same use before the special-purpose design was introduced. We have already noted the economies in structural materials which were achieved; and even more important economies were achieved in miscellaneous materials. The tackling of a different design problem forced a reconsideration of the design of every part, and in fact the special-purpose design had no part in common with the general-purpose design. Since the usage of miscellaneous materials is much less closely associated with the range of uses covered than is the usage of structural materials, it is probable that some of the economies achieved on the special-purpose design would have been applicable to a general-purpose design. A re-design of the general purpose motors might have yielded economies which, while less impressive for washing-machine motors, would have spread over a wider range of uses. Be that as it may, the comparison between the two designs at D seems to indicate that economies can stem from the re-thinking of problems necessitated by the introduction of a completely new design. But the fact that C's usage of miscellaneous materials on an old design was so much lower than D's usage on a new design indicates that even a thorough re-thinking may not be an effective substitute for a longer-term search for economies within a given design framework. In so far as such a search proves relatively unsuccessful, the rewards from the introduction of a new design may be greater; but the introduction of a new design does not necessarily secure many, or even most, of the economies uncovered by patient work on the details of an established design.

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[1] As is indicated by the adjustment to the cost figures in Table I to take account of these transfer effects.

B was, by comparison with C and D, a newcomer to F.H.P. motor manufacture, and it was still feeling its way towards effective solutions to design problems. Its latest—completely altered—design had been introduced a few years previously, and there had been few modifications by 1954.[1] As at D, a new design did not secure economies in the usage of miscellaneous materials comparable with those achieved by C; and only time would show whether modifications to B's design would be as productive of economies as C's, or as unproductive as D's modifications to its general-purpose design.

The comparison of a single trio of equivalent motors has shown that a special-purpose design for washing machine motors permitted economies on certain materials; it was a consequence of decisions to standardise by confining production to adaptations of a single general-purpose design that there was some excess usage of materials in washing-machine motors. But we would emphasise that it was only to a very limited extent that differences in material usage on the basic motors could be traced back to this standardisation decision *per se.* The two factories which took essentially similar standardisation decisions showed marked differences in material usage, and the factory with a special-purpose design did not show a lower overall material usage than one of the factories producing to a general-purpose design.

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[1] It is possible that the arrangements for servicing motors produced at B made it desirable that design modifications should be comparatively infrequent.

Multi-Product Comparisons

Single basic designs: B and C

The unity of design at B and C makes it likely that comparisons of other equivalent motors will, for many materials, yield results similar to those for the basic motors. An appropriate technique for extending the scope of the comparisons is therefore one which examines whether the adaptations of the basic design to cater for other uses involved a greater usage of materials, *in relation to the usage on the basic motor*, at one factory than at another. To simplify the text, the term ' relative usage ' will be used to describe, for specific materials or for all materials, the relation between comparative usage on the basic motor and that on other pairs of equivalent motors.[1]

Detailed analysis of relative usages reveals that for most materials, the basic motor comparison was reasonably representative. For example, the major differences for structural and miscellaneous materials persisted over the whole range of output.[2] Marked divergences from the pattern established for the basic motor can be traced back to two sources: first, to major components of a kind not needed on washing-machine motors, such as the capacitor fitted to motors for use in refrigerators; and second, to electrical steel—one of the most expensive materials—for which the basic motor comparison was decidedly unrepresentative.

Table II shows that for every ' new ' component studied, a low relative usage[3] went with a relatively high proportion of output incorporating that component. It is easy enough to see how such an association could arise. Given the distribution of its output, a factory's energies can most fruitfully be directed towards achieving savings on materials which bulk large in its material bill. Consider the four components for which B had a lower usage. It may be calculated that if B had used components as expensive as those used by C, its material bill would have been nearly 7 per cent higher; whereas if C

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[1] Let material usage (or usage of a specific material) on $\begin{cases} \text{the basic motor at } B=P \\ \text{the basic motor at } C=Q \\ \text{motor } N \text{ at } B=R \\ \text{motor equivalent to } N \text{ at } C=S \end{cases}$

Then relative usage at B for motor $N=100\left(\frac{R}{P}\div\frac{S}{Q}\right)$.

An important advantage of this formulation is that it is only necessary to establish the relation between usages on motors produced in the *same* factory. Since cost accounting data for materials are consistent for different motors from the same factory, reasonably accurate measures for R/P and S/Q can be derived from cost accounts: something that was not possible in the basic motor comparison (P/Q).

[2] Though C's advantage on miscellaneous materials was less marked on equivalent outputs than on the basic motor, mainly because some of the parts incorporated in the basic motor were not needed for certain other uses.

[3] The measure of usage for new components is cost adjusted for transfer effects. Whilst no great accuracy can be claimed for this measure, the differences between factories are so great that only very substantial errors could modify the picture which emerges.

TABLE II

Relative Material Usage for Specimen Motors incorporating New Components,[1] B and C

(Relative usage on basic motors=100)

New component	*Specimen relative material usages at B*[2]	*Percentage of output incorporating new components*	
		at B	at C
V	89	29	8
W	95	25	4
X	94	14	2
Y	98	5	5
Z	105	1	8

[1] Major components used on some motors, but not on the basic motor.

[2] A figure greater than 100 indicates a higher relative material usage at B. The relatives are calculated by comparing usages on the basic motors with usages on motors which differ from the basic motor only in respect of the variation necessarily associated with the incorporation of the new components. There is an arbitrary element in these calculations. Not all the motors postulated in the calculations were in fact produced, since there was no call for motors offering a combination of the high-torque electrical characteristics of the basic motor and the characteristics associated with some of the new components.

had used components as cheap as those used by B, it would only have lowered its material bill by some 1½ per cent. Because so many of these components were used at B, care in their design and care in the choice of suppliers paid off in substantial savings. But C could afford to concentrate its efforts on components which bulked larger in its material bill. The argument can be taken a stage further back. The distribution of output is only ' given ' in the sense that a count of output over a certain period reveals a certain distribution. Within the limits imposed by the total demand for any particular type of motor, a factory may decide to push its sales of some motors particularly vigorously. In so far as it is successful, it may acquire a reputation in some markets which will attract further orders for such motors. A sort of snowball effect can ensue—an expansion in the sales of motors in markets where profit margins may be relatively high (or opportunities for price-cutting relatively great) because costs are relatively low, creates the conditions in which the search for further cost economies becomes more valuable. We have no evidence of deliberate specialisation in the designs; this is an example of the *de facto* specialisation referred to in our previous article.[1] It must however be admitted that we were rather astonished by the regularity and magnitude of the effect—plausible generalisations are rarely confirmed so dramatically.

Entirely different issues are raised by divergences in the relative usage of electrical steel. In each factory, the fundamental standardisation decision was that a wide range of uses should be catered for by adaptations of a single basic design: and we noted that the (material) cost of this standardisation was some ' excess ' usage of material in motors for all uses except those with the most stringent requirements. The most important subsidiary standardisation decision was to limit the number of sizes of motor by confining production to a few different lengths of electrical steel core. The factories conform to the recommendations of the British Standard that they should produce motors of specified horse-powers and not of any intermediate powers. The recommended powers are ⅛, ⅙, ¼, ⅓, ½, ¾, and 1; but for most electrical types —for example, motors constructed to work on a three-phase electrical supply are of a different electrical type from those constructed to work on a single-phase electricity supply—only four of these powers (i.e. ⅙, ¼, ⅓ and ½) were covered by adaptations of the single basic designs. Since the average jump from one power to the next is over 40 per cent, any decision to use the same electrical steel core for motors of the same electrical type but of different power must involve substantial excess usage of this expensive material. So standardisation normally takes the form of using the same core in motors of different electrical type; and this is likely to involve some excess usage—the use of more steel in certain types than is strictly necessary for their functioning.[1] As between B and C, there were differences in the detail of designs, and in the precise form of standardisation adopted, so that the excess usage was not distributed in the same way over the various electrical types.

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[1] BULLETIN, Vol. 22, August 1960, p. 157.

Consider one example. The cores used in the basic motors are also used in industrial motors to work on a three-phase supply. The basic motors are equivalents, but the three-phase motors with the same cores are not. The equivalent at C of B's three-phase motor has a core 25 per cent shorter than that used in the basic motor, and so the relative usage of steel on this particular pair of equivalent three-phase motors is 25 per cent lower at C. The most plausible explanations are that there was an excess usage on the basic motor at C, and/or an excess usage on the three-phase motor at B.[2] This sort of divergence in relative steel usage for different electrical types is likely to be systematic, since for each type higher power was normally provided by producing a motor with a longer core. In Table III output is classified into four electrical types. For two of these types—one being motors of the same type as the basic motor—the basic motor comparison was roughly representative; and for the other two it was decidedly unrepresentative. On motors of these latter types, C had a much lower average relative usage:[3] with the suggested corollary that at B excess usage was found mainly on these types, and at C it was found mainly on the types for which the basic motor was representative. The average excess—which is what determines the suitability of the core

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[1] To some extent, an excess usage of steel may be offset by reducing the amount of copper wire in the motor, given that there were no comparable standardisation decisions for copper wire. Detailed comparisons of copper wire usage are extremely complicated. Our findings were that on average, over the whole range of output, a higher relative usage of steel was far from offset by a lower relative usage of copper wire. This does not, of course, imply that such an offset was unimportant for all motors in that range.

[2] It would be possible, though not very plausible, to argue that there was no excess usage of steel on either of these motors, because differences in the details of the designs adopted had the effect that one factory's design was peculiarly well suited to the production of a particular electrical property, for which the design of the other factory was relatively unsuited. Electrical tests suggest that such effects were present, but not to an extent sufficient to account for much of the observed difference in usage.

[3] Average relative usage is a weighted average of relative usages for the various motors of specified types. There are therefore two measures of average relative usage for each type, one based on B's composition of output, and the other on C's composition of output.

TABLE III

Relative Usage of Electrical Steel, by electrical type of motor

(Relative usage of electrical steel on basic motors = 100)

Electrical type	*Percentage of total output*		*Average relative usage at B*[1]	
	at B	at C	on B's output	on C's output
1 (includes basic motor)	37	70	100	99
2	29	8	104	101
3	30	15	120	130
4	4	7	118	127
All types	100	100	108	105

[1] A relative greater than 100 indicates a higher average relative usage of electrical steel at B. The relative usages on particular motors of the type specified are weighted in accordance with the importance of such motors in B's output, and in C's output.

lengths chosen—thus depended mainly on the relative importance in output of the various types.

But there were complications at both extremes of the power range, with far from negligible effects on relative usage. C's lower relative usage on equivalent motors of types 3 and 4 implies that motors of these types with a similar usage of steel relative to the basic motor were more powerful at C. Since this relationship holds for the shortest cores used, the least powerful motors produced at C of these types were more powerful than the least powerful motors produced at B. There were therefore no technical equivalents at C of B's least powerful motors, and indeed there could not have been unless C had introduced an additional, even shorter, core length, with some consequent loss of standardisation. So C could cater for the same uses only by using a core which was adequate for higher-powered motors, and there is evidence that in some cases it did this. The particular form of standardisation at C, which had the effect of reducing excess usage of steel on most motors of types 3 and 4, also entailed a considerable excess usage on a few motors. But because we do not know how many of C's motors were supplied to customers who would have been satisfied with a low-power motor, we can only assume that they *all* went to customers who needed the higher power. Thus the comparisons in Table III of average relative usage of steel based on an output of C's composition must be biased against B, in that B gets no credit for the economies which derive from its ability to supply low-power type 3 and 4 motors. When the comparisons are based on B's output, however, credit is given, since we can reasonably assume that C would have supplied higher-power motors to meet the demands satisfied by B's low-power motors. Consequently, in such comparisons, B's much higher relative usage on most motors of these types was in part offset, because it did not have to provide some users with more power than they needed.

At the upper extreme of the power range the issues are rather different. Extreme uses may be catered for by over-supplying power, but not by under-supplying it. B's spread of core sizes was wider than C's; its longest was 2¼ times as long as its shortest, as against twice as long at C. As a result, B was able to supply one type of motor at the upper end of the power range with an overload performance which C could not quite match—though it did produce a near-equivalent which would probably be as satisfactory in some uses. So B's decision brought a few additional uses into the range which could be catered for by adaptations of its basic design: but at the expense of incurring some excess usage—about 10 per cent—on the higher power motors which did not need the extra performance. In the measures of relative steel usage, we have taken the near-equivalents as equivalents, ignoring the fact that B catered for a few additional uses—and in consequence there is another slight bias against B in the calculations. B's slightly higher average relative usage on type 2 motors was largely attributable to the additional steel incorporated into high-power motors. The greater usage was more noticeable on B's output since it produced a relatively large number of high-power type 2 motors.[1]

When the average relative usages on the various electrical types are combined to obtain a comparison of average relative usage covering all output, it appears that on its own composition of output B's average relative usage was 8 per cent higher than C's would have been on such an output: and that B's average relative usage on an output of C's composition would have been 5 per cent higher than C's. The latter calculation is biased against B, but even so it appears that B's average relative usage of steel shows up more favourably in calculations based on C's output than in those based on its own output—quite the opposite association to that found in the analysis of usage on new components. This is no case of *de facto* specialisation—on the contrary, B's forms of standardisation seemed more suited to C's output, and *vice versa*. But as B's relative usage is higher on *both* outputs, it follows that the basic motor comparison for electrical steel was unrepresentative, in that a comparison over the whole range of output would be more favourable to C and less favourable to B.

This analysis has been rather technical, but we may illustrate some of the points at issue with the help of a simple model. Suppose the market was such that the lowest possible usage of electrical steel could be achieved by making equal numbers of cores of every possible length between the longest and the shortest. Then if the longest was 2½ times the length of the shortest, it can be calculated that a decision to standardise on two core lengths would involve an excess steel usage of 21 per cent, on four lengths would involve an excess of 11 per cent, and on eight lengths 5 per cent.[2] In reality, there are two reasons why excess usage might be greater or smaller than this. Firstly, the characteristics offered to the market may be such that there are discontinuities, or jumps, in the lengths technically necessary. Most obviously, these factories offer motors of specified powers only. There is no unique relationship between power and necessary core length, since the relationship is affected by electrical type and the details of design: but it is nonetheless likely that there will remain some discontinuities in the distribution of technically suitable sizes. If the standard sizes were chosen in such a way as to take fullest advantage of such discontinuities, excess usage would be smaller than indicated by the model. Secondly, different motors are not demanded in equal numbers. Evidently total excess usage will be low if the excess can be concentrated on motors in low demand, and if motors in high demand are produced with near-minimum usage.

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[1] This bias could have been reduced by excluding B's extra-performance motors from the comparative study on the grounds that C produced no strict equivalents. But in fact such an exclusion would have been very unfavourable to B; not only because type 2 comparisons are less unfavourable to B than comparisons for types 3 or 4, but also because type 2 motors incorporated ' new ' components for which B's relative usage was low.

[2] These percentage excesses are calculated from the formula $\frac{100(t-1)}{S(t+1)}$, where S is the number of sizes and t the ratio between the largest and the smallest required size.

From the distribution of output given in Table III, it appears that C was in a position to secure a low excess usage by producing type 1 motors with near-minimum usage; whereas B, with a more even spread of output by electrical type, stood to gain more from a technically-determined standardisation decision which took advantage of discontinuities in the distribution of technically suitable sizes. We cannot be certain that there was excess usage at C on type 1 motors, but it is suggestive that the form of standardisation it adopted was such that on every other type of motor its relative usage was lower. One consequence was that its form of standardisation showed to greater advantage on outputs very different from its own, with a lower proportion of type 1 motors.

But no factory can afford to change its standardisation decisions frequently, for the costs of change—in re-tooling, and in producing revised specifications—are considerable. The balance of markets had changed; type 1 motors were less important in C's output in 1952 than they were in 1954. The technical background had also changed: for example, innovations in the treatment of electrical steel had over time raised the potential power output from a given core size. For both these reasons there is a risk that a standardisation decision appropriate to a particular set of circumstances may become obsolete. The longer-run costs of any particular decision cannot be predicted with any accuracy: nor can they necessarily be avoided by producing a less standardised output. Indeed eight once well-chosen lengths may turn out to involve a greater excess usage of steel than four chosen with less care. A willingness to alter the form of a standardisation decision which becomes inappropriate—despite the costs involved in the change—can be more important in reducing excess usage than a willingness to produce a less standardised output.

We have analysed the most important divergences in relative usages of particular materials and components. Table IV summarises relative usages of all materials for motors in output as a whole. The spread of relative usages on individual motors was wide—on some equivalent motors C's relative usage was up to 20 per cent lower, while on others B's relative usage was up to 25 per cent lower. For such motors, the basic motor comparison was

TABLE IV

Relative Material Usage for Equivalent Outputs, B and C

(Relative usage on basic motors = 100)

Relative usage	*Percentage of B's output*	*Percentage of C's output*
C's relative usage for equivalent motors lower than B's by:		
15—20%	—	8
10—15%	15	9
5—10%	9	4
0—5%...	1	—
	25	21
Relative usage as on basic motor...	33	62
B's relative usage for equivalent motors lower than C's by:		
0—5%	8	8
5—10%	4	—
10—15%	9	7
15—20%	16	2
20—25%	2	—
	42	17
Relative material usage for equivalent outputs[1] at B	97	102

[1] Weighted by relative material costs at C.

wildly unrepresentative. Considerable economies were achieved by both factories in the adaptation of their basic design to cater for certain uses. In general, B's relative usage was lower on motors of the electrical types for which its relative usage of electrical steel was very little higher, and which incorporated one or more of the new components for which its relative usage was lower. C's relative usage was lower on motors which were of the electrical types on which its relative usage of electrical steel was much lower.

But when relative usages on all motors are combined to give a measure of average relative usage on equivalent outputs, the divergences for individual motors in the main cancel out. It appears that the basic motor comparison was very nearly representative of a comparison of usage on all output, and that it makes only a limited difference whether the comparison is based on B's or C's output. Although there was a definite tendency for each factory to produce a higher proportion of those motors which it could make with a relatively economical use of material, the difference of 5 per cent between the two overall measures appears rather trivial in relation to the observed difference for the basic motor. But the rough representativeness does not mean that the basic motor comparison gave an adequate picture. For electrical steel, it was misleading: for new components it was uninformative. Furthermore, the cancelling out of divergences must be regarded as fortuitous. Economies for new components were associated with greater importance in output, whereas economies in electrical steel were associated with lesser importance in output. The former association could plausibly be explained in terms of *de facto* specialisation: the latter was the result of the working out of particular standardisation decisions. The object of a detailed analysis is to examine the causes of differences in material usage—the fact that quite unconnected differences may cancel out is unimportant.

As between B and C, the basic motor comparison was essentially a comparison of basic designs for a wide range of output. The result that the basic motor comparison was representative contributes nothing to an understanding of the problems of adapting a design to cater for a range of uses: but in so far as it underlines the importance of achieving economies on the basic design, it is valuable. Where there is so much in common between all motors of the same basic design, economies in this or that adaptation have to be substantial—and closely associated with the distribution of output—to have much effect on total material usage. It might have been true that C's economies on the basic design were offset by dis-economies in the adaptation of that design—but it wasn't.

Single and multiple basic designs: B and D

D produced motors to several basic designs, so that any comparison of a single pair of equivalent motors cannot be expected to be representative of comparisons over a broader range of output. Consider the comparison of relative usages between B and D, shown in Table V. This Table is the analogue of Table IV in the B—C comparison, summarised to show for each design at D the spread of relative usages on equivalent motors. The spread of relative usages for each design was very much narrower than in the B—C comparison. For designs D1, D3, and D4, the comparisons cover a much narrower range of uses, so smaller divergences would be expected. Design D2, however, covers almost as broad a range of uses as the basic designs B and C: but the divergences between B and D for particular adaptations were less marked than those between B and C. Such evidence as there is[1] points to a rather greater similarity in relative usages on new components, and many fewer differences in the working out of standardisation decisions for electrical steel. A comparison of C and D would show wider spreads of relative usages, but a detailed analysis would result, for the most part, in a repetition of points already made in the B—C comparison. So we may

TABLE V

Relative Material Usage, by Design at D, for Equivalent Motors,[1] *B and D*

(Relative usage on basic motors=100)

Design at D	*Relative usage at B*
D1 (washing machine)	97—102
D2 (general purpose)	83—97
D3 (small)	97—104
D4 (large)	57—71

[1] Several motors from each design at D compared with their equivalents at B. For each design, the lowest relative shown is for the pair of motors of that design for which relative material usage was most favourable to B, and the highest relative shown is for the pair of motors for which relative material usage was most favourable to D.

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[1] The information on material usage on particular motors was far less comprehensive at D than at the other two factories. Furthermore, transfer effects were more important.

TABLE VI

Equivalent and Non-equivalent Output, B and D

	Percentage of output at D	
	Own output	*Output equivalent to B's*
Motors with equivalents:		
Design D1	63	49
Design D2	18	41
Design D3	4	1
Design D4	4	7
Total D1 *plus* D2	81	91
Total, all output	89	99
Motors without equivalents:		
Design D3	4	—
Design D4	1	—
Design D5	2	—
Other	4	1
Total	11	1

concentrate on a comparison between B and D, in which the consequences of decisions to produce several basic designs show up more clearly.

The recently-introduced design D1 was a special-purpose design specifically intended for washing-machine use, and the basic motor at D was one of the range of motors produced to this design. When D1 motors are compared with their equivalents at B, the basic motor relative lies near the centre of the small spread of relative usages. But for the general-purpose design D2, the whole distribution of relative usages is shifted in B's favour. On no adaptation of that design was the comparison of usage more favourable to D than on any D1 motor, and for some it was very much less favourable. So certainly the introduction of design D1 saved materials: for example, the material usage on the basic motor was about 8 per cent lower than on the D2 motor which would have been supplied for the same use a few months previously. The total economies stemming from the introduction of a special-purpose design depend on the composition of output, and Table VI shows that motors of design D1 were far more important in D's output than were the equivalents in B's output. D was in 1954 better placed than B to secure major savings by specialising the design of washing-machine motors. It can be calculated that the introduction of design D1 lowered D's total material bill by 6 per cent: whereas B's savings, had it introduced a special-purpose design as economical in relation to its general-purpose design, would have been 4 per cent. As always, the case for any particular form of specialisation or standardisation cannot be considered independently of the composition of output, and—since decisions once taken are expensive to reverse—on expectations of output composition in the future. That outcomes may differ from expectations is the main risk attending a specialisation for a narrow set of uses.

D1 was not typical of D's design decisions. All the other designs were general-purpose designs, from which D was able to produce motors offering a wide range of output characteristics. D3 was a smaller motor, catering for lower powers than D2; D4 was a larger motor, and D5 was even larger. Table VI indicates that B was able, from its single general-purpose design, to match a high proportion of the motors produced to these designs at D. In particular, most of D4 output lay within the range of B's designs, because demand for D4 motors was concentrated at the lower end of the power range served.[1] Referring to Table V, we see that relative usage on equivalent D3 motors was about the same as on the basic motor: the economies achieved on D1 were of the same order as those made possible by the production of a smaller, less substantial, general-purpose motor. If it were fair to suggest that the sole objective of design D3 was to save materials on motors equivalent to those produced by B's general-purpose design, and which might have been produced by an adaptation of D2, it would be fair to conclude that the comparatively small savings on material on a low proportion of output could hardly have justified the introduction of a separate design. But this would not be fair. Some D3 motors were of a power so low that they could not be matched by B: and given a decision to cater for those uses with a separate design, it was economical to use that design to produce motors which might have been produced from D2 if D3 had not existed.

On any comparative basis, D4 was a very expensive design. For the same reason that it was economical to use D3 for motors which might have been produced from D2, it would have been highly economical to use design D2 for any motors in the D4 range. We cannot judge how far D2 might have been stretched: we can only note that B's single general-purpose design was stretched in such a way that it could match the performance of some D4 motors. It has been pointed out that B's design was stretched rather further at the higher end of the performance scale than C's, and in fact C could match the performance of many fewer D4 motors. The real value of B's stretching was that it enabled B to produce some motors the performance of which C could not quite match, and which D could only match by supplying a far more expensive design. It thus had a marked competitive advantage in a limited field, and it can scarcely be accidental that motors for these uses bulked far larger in B's output than they did in D's.

Stretching a general-purpose design in the direction of higher performance may, however, involve a greater excess usage of materials on other motors produced to that design—an effect which was observed in the B—C comparison.[2] Stretching a design in the direction of lower performance may involve the production of motors which are at a disadvantage because they have to compete with motors produced from designs which exploit the

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[1] Motors produced at B offered the same technical properties as these D3 and D4 motors, and it is therefore likely that they were equivalents in many uses. But B's and D's motors were structurally so different that there will have been some uses for which they were not equivalents.

[2] See above, p. 121.

TABLE VII

Relative Material Usage for Equivalent Outputs as a Whole, B and D

(Relative usage on basic motors=100)

	Average relative usage at B	
	D's composition of output	*B's composition of output*
Comparison based on:		
D1 *plus* D2...	98	94
All equivalent output	95	89

economies derivable from catering to a lower power range: B's usage compared less favourably on equivalents to D3 motors than on equivalents to D2 motors. It can never be easy to decide how far it is worth stretching the range of output catered for by a single general-purpose design. Where, as at D, more than one general-purpose design was produced the problem is even more complicated. A decision on the appropriate range of output to be catered for by each design may become obsolete, but any alteration in the range of output from one of the designs involves an alteration in the range of uses catered for by other designs. For example, design D4 contributed 5 per cent of D's output, and it might have been possible to produce 4 per cent at a much lower material cost by stretching the D2 design in the same way as B stretched its general-purpose design. In turn, the 1 per cent of output then left to D4 might have been produced by stretching D5 downwards, thus eliminating one basic design altogether and contributing to a somewhat greater standardisation of production without reducing the range of output catered for. Alternatively, the range of output catered for by both D4 and D5 might have been altered—perhaps with consequential design alterations—so that an even wider range of power was covered by the same number of basic designs. We cannot, of course, comment on the technical feasibility of such adjustments: the point is that any adjustment to one design must have implications for other designs. The temptation to overlook advantages to be gained at the cost of multiple adjustments must be strong.

Table VII presents alternative measures of relative material usage on equivalent outputs. Because the basic motor was of the economical D1 special-purpose design, the basic motor comparison must give an unduly favourable impression of D's material usage on a wider range of output. But it is not possible to give any single measure which will indicate how much too favourable to D that comparison was. If the comparison is confined to D1 and D2, B gets no credit for its ability to cater for uses which D did not cater for from these designs: if the comparison embraces all equivalent output, D gets no credit for its ability to cater for uses which B could not cater for from its design. Since D1 motors were so important in D's output, comparisons based on its own composition of output are less unfavourable to D; because equivalent D4 motors were so expensive in material, the broader comparison is more unfavourable to D.

Considering that there was hardly any other pair of equivalent motors which would give a comparison of usage so favourable to D as the basic motors, it is perhaps surprising that comparisons over a much wider range of output do not turn out to be even more unfavourable to D. They are not more unfavourable because the motors on which D shows up most favourably are very important in total output, whereas those on which it shows up most unfavourably are relatively unimportant in total output. The B—C comparison underlined the importance of achieving economies in the basic design: the D—B comparison underlines the importance for material usage of achieving economies on those few motors which accounted for a high proportion of output.

D concentrated on these motors to the extent of introducing a separate basic design. The economies which it was able to achieve on individual motors were only of the order of 8 per cent: but the motors were so important in its output that its material bill on equivalent output was lowered by some 6 per cent. Part of this advantage was offset by its production of expensive D4 motors for uses which might have been catered for by stretching the D2 general-purpose design in the way that B stretched its design. Had it stretched the D2 design, its material bill might have been 3 per cent lower than it was. The latter diseconomy was not directly related to the former economy; the introduction of design D1 did not imply that the range of D2 should not be stretched. The range of output catered for by the general-purpose designs could, if it had been considered desirable, have been adjusted whether or not D1 had been introduced. It is likely, however, that D1 would not have been introduced if several basic designs had not already been in production: and it is possible that the introduction of a new design, with all the concentration of effort which that required, may have diverted attention from the more complicated problems of securing economies on the general-purpose designs.

CONCLUSION: DESIGN IN MULTI-PRODUCT FACTORIES

To suppose that this study could lead up to a single, tidy conclusion, of the sort that X was A per cent more economical in its use of materials than Y, would be to underestimate, and to misunderstand, the problems of comparing multi-product factories producing different outputs to their own designs. The basis of comparison has to be defined: we have compared the usage of materials necessitated by the design of equivalent motors and equivalent outputs. It is only in this specific sense that our comparisons can show whether one factory was more economical than another in its use of materials. As Table VIII shows, no unique measure can be given of how much more economical, in this sense, any factory was. For the basic motors, we could not—despite the very comprehensive information at our disposal—give exact measures of differences in usage. Comparisons over a range of output must acknowledge that factories catered for that range in different ways, and that they produced outputs of different composition. The measures of relative usage indicate that what is economical for one output may be less economical

TABLE VIII

Overall Comparisons of Material Usage

	B compared with C: usage at C=100		*B compared with D: usage at D=100*		*D compared with C: usage at C=100*	
Usage on basic motors[1]	117 ±3		116 ±4		101 ±3	
	Comparison most favourable to:		Comparison most favourable to:		Comparison most favourable to:	
	B	C	B	D	D	C
Usage on equivalent outputs relative to usage on basic motors[2]...	97	102	89	98	102	104
Usage on equivalent outputs ...	113 ±3	119 ±3	103 ±4	114 ±4	103 ±3	105 ±3

[1] From Table I.

[2] B-C comparisons from Table IV, B-D comparisons from Table VII.

for another, and even then leave unanswered questions relating to output outside the common range.

Nevertheless, the summary comparisons of overall material usage on equivalent outputs shown in Table VIII leave little doubt that C was more economical in its usage of material than either of the other factories. Not only could C produce its own output more economically than the other factories could produce an equivalent output: it could also produce more economically outputs equivalent to those produced at the other factories. B appeared least economical in its material usage, and D occupied an intermediate position. No single figure can be given for the magnitude of the difference between B and C: but even on the comparison most favourable to B, C's usage seems to have been at least 10 per cent lower. A rough order of magnitude is that direct material costs in motor production were about 4—5 times direct labour costs: a saving of 10 per cent in material usage can be thought of as equivalent, in its effect on direct costs, to a 40—50 per cent reduction in direct labour usage. Comparatively small economies in material usage can, in a sense, offset substantial differences in direct labour productivity. It is therefore worth while to examine the ways in which different solutions to design problems contributed to differences in material usage.

All these factories decided to cater for a variety of uses. Obviously if a factory specialised to the extent of catering for a single use, it would produce to a special-purpose design, and would concentrate its efforts on the improvement of that design. But when many uses are to be catered for, the relative advantages of more or less standardisation come into question. Standardisation—providing the same *motor* for different uses, or using the same *components* in different motors—must involve some excess usage of materials, a form of wastage which has to be set against the economies to be derived from the consequent simplification of the production problem.

The uses which can be served by a particular motor are in large measure determined by the technical properties it offers. Motor standardisation took the form of limiting the variety of technical properties offered: most importantly, all factories followed the recommendation of the British Standard that certain specific horse-powers should be offered. In general, too, similar decisions were taken on the varieties of other properties to be offered in the 'standard' range of motors. Since the factories standardised their motors in the same ways, we can throw no light on the advantages or disadvantages of this form of standardisation. Indeed it is only because their motor standardisation decisions were so similar that equivalents could be identified and meaningful comparisons of material usage made. There were, it is true, a few motors at the extremes of the power range for which the equivalence approach was not wholly satisfactory. For these, motor standardisation decisions differed: but these differences were usually closely associated with the form of component standardisation adopted.

So in these comparisons we could concentrate on the consequences of design and component standardisation. The general practice was to produce a range of motors conforming to the same basic design: different motors were essentially adaptations of this design, with many components in common. At B and C, all motors produced were adaptations of a single basic design, and the excess usage involved in this standardisation decision was mainly concentrated on structural materials. Since the range of uses covered heavy-duty as well as light-duty uses, the basic design had to be stronger than would have been necessary if only light-duty uses were catered for, and both B and C had to 'waste' material on light-duty motors. This was a cost of standardisation which both paid; yet the usage of structural materials, was, in 1954, far greater at B than at C, despite the fact that a very similar range of uses was catered for. Judgments on technical and market issues were involved in the choice of material, and in the way the chosen material was to be used; and decisions once taken could not easily or quickly be revised. B's decisions on structural materials had turned out to be more costly than had been anticipated, and this was a main cause of its greater total usage of materials. Decisions on the form of standard design were as important in determining comparative material usage as the decision to standardise.

It follows that the material economies to be derived from the introduction of a special-purpose design to cater for certain uses cannot be assessed independently of the usage on the general-purpose design motors which would otherwise be supplied. D's general-purpose design D2 was used for washing-machine motors prior to the introduction of the special-purpose design D1. Design D1 achieved substantial economies on structural and miscellaneous materials, and material usage was about 8 per cent lower than on equivalent motors of design D2. Part of the economies on miscellaneous materials could probably have been achieved on the general-purpose design, and the economies directly attributable to design specialisation were of the order of 4—5 per cent. Since D2 was structurally rather similar to C's design, savings of this magnitude on particular motors could have been achieved by C if it had been able and willing to produce a design as economical as D1. B's savings, given similar conditions, could have been at least twice as great.

Even the comparatively modest savings achieved on particular motors by D were valuable because these motors bulked very large in its output—as indeed they did in the output of the other two factories. But it is relevant to note that there was no other group of motors for which specialisation of design would have been so valuable. For a very few motors, the economies might have been slightly greater; but none of these motors were anything as important in the distribution of output. In effect, unless the introduction of a special-purpose design is accompanied by a decision to restrict the range of uses catered for, a general-purpose design has to continue in production—as it did at D.

B and C were able to confine production to adaptations of a single general-purpose design by restricting the range of uses catered for. D catered for a much wider range of uses, and for this reason produced several general-purpose designs. Because many of the motors produced to D's smaller and larger general-purpose designs did not have equivalents at other factories, no satisfactory assessment of these designs was possible. But the comparisons for the limited number of equivalents did serve to emphasise the importance of decisions concerning the range of output to be catered for by each of the general-purpose designs. D's very much higher usage on a few motors might have been avoided if they had been produced from the smaller and cheaper D2 design, rather than from the D4 design. Evidently it is much easier to standardise effectively if the decisions on the range of output to be covered can be geared to the form of standardisation adopted.

Within basic designs, the most important standardisation decision concerned the number of electrical cores to be produced. Here again, B and C took very similar decisions: and here again, excess usage was much influenced by the particular form which standardisation took. Because standardisation took a rather different form at the two factories, excess usage appeared on different electrical types of motor; so that excess usage over output as a whole was determined by the composition of output produced. B, with its rather more even distribution of output between electrical types, was in a relatively fortunate position in that a different form of standardisation would not have led to markedly higher or lower excess usage. But at C, output was heavily concentrated on a type of motor for which the form of standardisation adopted seemed to imply a greater excess usage. There were also borderline problems at the extremes of the ranges of output catered for by the single basic designs, somewhat analogous to the borderline problems between different basic designs at D. B's decisions widened slightly the range of uses that could be catered for, at the cost of greater excess usage on some other motors; and C's decisions involved a considerable excess usage on a few motors which did not fit neatly into the chosen form of standardisation.

The upshot of the analysis we have been able to carry through is that no simple generalisations about the consequences for material usage of design specialisation or standardisation can usefully be made. It is of course true that, given a range of uses requiring different motors, there are potential material savings from design specialisation. But in this industry, at any rate, we can rule out as absurd any suggestion that the design of each motor produced could be tailored precisely to its use. Standardisation there must be: and the problem poses itself in the form of more or less standardisation, rather than in the simpler form of complete standardisation *versus* complete specialisation. D's output was less standardised than that of B or C, partly because of a deliberate decision to specialise (D1) and partly because a range of output was catered for which made a similar degree of standardisation impossible. There were gains from the deliberate specialisation, and losses from the way in which the wider range was catered for by non-specialised designs. At B and C, the degree of standardisation was very similar: but the material costs of that standardisation were very different. A decision to standardise is the beginning, rather than the end, of a complicated story; how much that decision costs in materials will largely be determined by the detailed interpretation of the decision.

The importance of attention to the detail of design was underlined by major economies in material usage which were only indirectly associated with standardisation or specialisation decisions. The most striking example was the economy in miscellaneous materials at C. It was these savings which enabled C to produce washing-machine motors from its general-purpose design as economically as D produced a motor from its special-purpose design. B, in its turn, achieved substantial economies on those new components which were incorporated into some motors which bulked large in its output. D's usage of miscellaneous materials in its special-purpose design was lower than on its general-purpose design partly because the design was specialised, but mainly because the working out of the details of a completely new design enabled this factory to secure economies which could have been achieved on a general-purpose design. The common thread linking these examples is that material usage can be reduced by taking pains with the detail of design.

The economies at C indicate that there is much to be gained from an approach which involves a concentration of effort on the details of a design within an essentially unchanged framework: many economies cannot possibly be foreseen when a new design is introduced, and will only be revealed by patient work over a period of time. The danger of sticking to an essentially unchanged design is that the particular forms of standardisation chosen become more costly as markets and techniques change. Furthermore, sticking to a design does not necessarily mean that the potential economies will be exploited. The comparison between the general-purpose designs at C and D suggested that the latter factory had been less successful in its search for economies, and the introduction of the new design at D might be justified by the stimulus of having to think out design problems in a new context. But the comparisons leave no doubt that in 1954 C had achieved economies on its old design which were not matched by economies from the new designs at B or D; and that these economies were of major importance in contributing to its lower material usage.

So much for the sources of the differences in material usage necessitated by the designs adopted in these three factories. Obviously the *pros* and *cons* of different design solutions cannot be assessed merely by comparing material usages. Though we cannot in this article pursue the implications of design differences for the usage of other factors of production,[1] one general comment can be made. Comparisons of material usage seem likely to be loaded against design standardisation: in so far as there are economies to be achieved by producing a less standardised output, they will in the main be economies in material usage. Standardisation *may* be expensive in material, but there will be potential economies in the usage of other resources. Thus it is evident that D must have had a more complex production problem than either of the other two factories. In part, this was a consequence of decisions to cater for a wider range of uses, and to produce a wider variety of motors adapted to customers' individual requirements. But in part it was a consequence of a decision to use two designs for a rather narrower range of output than that produced by the other firms: and production to two designs meant that two completely different sets of components had to be produced. Of course it is possible that the advantages of greater design standardisation at B and C were lost through inferior techniques of organisation and manufacture: these are problems to be considered in the next article in this series, and all that can be said now is that their designs gave them a flying start. With this in mind, the fact that C's material usage was *lower* than D's is peculiarly significant. Conversely, it is also true that comparisons of usage of other factors seem likely to be loaded in favour of standardisation: in so far as D's usage of labour and overheads turns out to be higher *because* of its less standardised designs, it is relevant to note that its material usage would have been substantially higher if it had not introduced its special-purpose design.

Our general comment was phrased very cautiously, because it is not a conclusion of this study that standardisation *was* expensive in material. B's usage of material was relatively high, but C's was not. D did not achieve a material usage lower than C's by producing a less standardised output. We have stressed that material savings have to be worked for—and this means work for the design departments. The greater the standardisation of design, the greater can be the concentration on the details of design. Where, as at D, several completely different designs were in production, there must have been some attenuation of design resources. Even if resources were to be concentrated on one of the designs, at the cost of neglecting the others, any consequent material savings would be less important because they would only be achieved on a portion of output. It is relevant to recall that the important material economies achieved by D were relatively ' easy ' ones: the obvious savings in material obtained at the cost of producing an additional design. The important economies at C, by contrast, were ‘ difficult ’ ones, which did not involve any loss of standardisation. Of course, such economies could be achieved on each of several designs if more resources were devoted to design. But it is Hobson’s choice: either overhead costs have to be increased, or some of the material economies acheivable on a more standardised output have to be forgone.

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[1] It is important to note that because we have been analysing the relations between design and material usage, any differences of design which do not affect material usage have not been considered. One component may use the same material as another; but the one may be designed in such a way that it is much easier and quicker to produce than the other.

Economy in the use of materials is one, but only one, element in the more general problem of producing—and selling—a mixed output with a minimum use of resources. Subsequent articles will compare the usages of labour and overheads for the outputs produced to the designs analysed in this article.

WAGES IN COAL MINING

by T. P. HILL *and* K. G. J. C. KNOWLES

This article describes an econometric investigation into the factors influencing the inter-colliery pattern of wages in 1954. By means of multi-variate analysis, it is shown that well over half the variation in wages between individual collieries can be attributed to corresponding variations in labour productivity, types of labour and location. Moreover, by allowing in a systematic fashion for the effects of location, it is shown that the relationship observed between wages and productivity for all collieries taken together gives a quite misleading impression of the relationship actually found between collieries in the same district or coalfield. This illustrates the futility of attempting to estimate a relationship cn a global basis when there is a possibility of the relationship varying between particular sub-groups of the population.

An earlier version of this article was read as a paper to Section F of the British Association at Cardiff in September 1960.

We propose to examine average earnings per manshift for all manual workers (both surface and underground) in different collieries throughout the country in 1954. Our choice of 1954 was due to the fact that in the following year the wage structure for timeworkers was systematically overhauled so as to standardise wage rates for similar types of worker in different pits—which meant, in effect, the beginning of a progressive elimination of some of those 'inter-plant' differences which students of wage structures would like to explain. It is true that collieries, in a nationalised industry, are not financially independent and competitive as are the mass of firms in private industries; but it is also true that the relative wage levels of different collieries, even seven years after vesting day, were still largely a legacy from earlier times.

In 1954 there were 875 pits operating in the industry, with a total labour force of just over 700,000 men producing some 214 million tons of coal during the year.[1] From these 875 pits we decided to exclude (*a*) those where extensive reorganisation was going on, (*b*) those in small outlying coalfields (notably Cumberland, North Wales and Kent) and (*c*) those for which—for one reason or another—the required data were incomplete. We were thus left with 710 collieries and 546,000 workers. Among these collieries, the variations in numbers employed, in productivity and in average earnings were as given in Table I.

If we make a rough comparison with other industries, we can say that the range of variation in the sizes of collieries is very much smaller than that of manufacturing firms, since the biggest of our collieries employs no more than 3,600 men (and only five exceed the 3,000 mark). Moreover, the distribution of colliery sizes is less skewed: only about 4 per cent of collieries employ fewer than 100 men while in engineering, for instance, the corresponding proportion is over 50 per cent.[2]

No such comparison is possible with productivity; but here the range of variation was considerable:[3] while the average was around one ton per manshift, some pits produced less than half and others well over twice this amount.

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[1] *Cf. National Coal Board Report and Accounts* for 1954.

[2] *Cf.* Hill and Knowles, 'The Variability of Engineering Earnings', BULLETIN, May 1956, p. 98.

[3] *Cf.* Sir Hubert Houldsworth, 'The Pits of Britain', *Transactions of the Manchester Statistical Society*, Sessions 1952–53.

TABLE I

Employment, Productivity and Earnings in Coal Mining in 1954

Employment	*No. of pits*	*Manshifts per ton*[1]	*No. of pits*	*Earnings per manshift (shillings)*	*No. of pits*
0— 199	93	<0.5	25	<38	22
200—	114	0.5—	56	38 & 39	84
400—	99	0.6—	67	40 & 41	172
600—	103	0.7—	98	42 & 43	169
800—	86	0.8—	114	44 & 45	136
1,000—1,499	101	0.9—	103	46 & 47	67
1,500—	73	1.0—	82	48 & 49	38
2,000—	19	1.1—	59	50 & 51	16
2,500—	17	1.2—	39	52 & 53	6
3,000—3,599	5	1.3—	25		
		1.4—	13		
		1.5—1.9	20		
		2.0 & over	9		
		Total of above pits 710			
Means[2] 768		0.93		42.7	

[1] The measure of manshifts-per-ton (which is of course the reciprocal of the usual measure of physical productivity) follows the N.C.B.'s practice in the collection of its statistics for the ' Colliery Profiles '.

[2] The means are not weighted by numbers of workers employed, and for this reason—as well as because of the difference in coverage—do not coincide with the averages for the industry as a whole which are given in the *N.C.B. Report and Accounts* for 1954 (manshifts per ton, 0.81; earnings per manshift excluding allowances in kind, 45.7 shillings). Since both productivity and earnings are positively correlated with size of colliery, our unweighted means tend to understate the position for the industry as a whole.

As regards earnings per manshift, however, the range of variation would seem to be considerably narrower than the range of hourly earnings in manufacturing. For instance, while we found that in engineering the coefficient of variation[1] of the averages of hourly earnings—even for timeworkers in a single occupation (fitters)—was 12.7 per cent,[2] the corresponding figure for the averages of earnings per manshift for all colliery workers was no more than 7.4 per cent. Over two-thirds of pits, in fact, had average earnings of between 40s. and 45s.; but still there were wage differences of over 15s. per shift at the extremes.

The data for this study, which were kindly made available by the National Coal Board, related to almost every aspect of colliery conditions. The statistics collected about each pit for the Coal Board's ' Colliery Profiles ' include details of levels and changes in employment, output, productivity, costs, profits and wages, as well as a mass of miscellaneous material on such items as disputes, labour turnover, degree of mechanisation, depth of shafts, thickness of seams, age of collieries, etc. At first it seemed possible, with this wealth of data, to undertake to ' explain ' wage differences more exhaustively than had ever been possible in other industries—for which comparable material is never available. On the other hand it was clear that the very existence of this *embarras de richesse* would create problems of analysing it. Even the decision to explore the various associations inherent in the data by using conventional multivariate regression analysis posed a formidable task of computation.

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[1] *I.e.*, the standard deviation normalised by being divided by the mean.

[2] In 1952, *cf.* Hill and Knowles, *op. cit.*, p. 102.

To cope with this, it was clearly necessary to have recourse to an electronic computer; and in fact the University had recently installed a Ferranti Mercury. Moreover, the Institute of Statistics was naturally interested in the design of programmes required for economic and econometric analysis: such programmes were being written by our colleague Peter Vandome, who devoted a great deal of effort to working on the Coal Board material since this seemed to provide an opportunity of testing not only the programmes themselves but also the general appropriateness of using a computer for processing large quantities of economic data.

It may seem surprising, in view of the very great number of potentially explanatory variables, that we ended by using so few (productivity, structure of labour force, and location) to account for wage differences. But this does not mean that the other variables were cursorily discarded: we naturally began by looking at the relationships between wages and these variables, both singly and in combination, and in the process we observed, also, the associations between the explanatory variables themselves. These preliminary examinations showed wages to be associated with quite a number of the other factors, but in many of these cases it seemed more plausible to assume that wages was the explanatory variable rather than the dependent variable.[1] For example, there is a strong correlation between wages and costs; but it is costs that are obviously influenced by wages, if only because wages are so large an element in costs. Labour wastage also turned out to be associated with wages; but here again wages was surely the dependent variable rather than *vice versa*? The moral of all this was to suggest two distinct but complementary lines of enquiry: the first (which is pursued in this article) to see how far other factors could reasonably be held responsible for wage differences; and the second (which is to appear separately) to examine, in turn, what impact wage differences themselves seemed to have on other variables—particularly on labour turnover. For the purpose of both these enquiries, it was clearly of value to have gained some idea of the correlations obtaining between most of the variables used (*e.g.* between profits and productivity, between recruitment and wastage, etc., etc.): indeed, the very observation of a large number of relationships itself suggested that certain lines of enquiry might be fruitful while others were likely to be sterile.

This kind of empirical approach appears unusual only because of its scale: such an undertaking is feasible only with the facilities offered by a modern high-speed computer. It is of course quite customary to study one's data and—for instance—to inspect their inherent relationships by means of two-way frequency distributions; but such a procedure becomes impracticable when one wants to examine multiple associations for many variables. Nor, once the decision to use a computer at all appears justified, is it particularly extravagant to compute a very large number of regressions: almost all the expenditure of research time goes into the writing of the programme and the preparation of the data and, once these have been fed into the machine, the marginal cost of an extra fifty regression equations is the same number of minutes of machine time.

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[1] In other cases (as for instance with technological and physical variables such as degree of mechanisation, depth of shaft and thickness of seam) there was some association with wages; but this was presumably due to a logically prior association with productivity—the chief explanatory variable in the analysis which follows. It is, for example, hard to see how wages could be *directly* affected by the road length to the coal face; but there is an association between road length and wages since, *ceteris paribus*, the longer the time spent in reaching the coal face the lower the output per manshift.

Detailed investigations of wages which distinguish between the wages paid in individual firms usually reveal so much diversity that the general appearance is one of chaos. Wage differences between neighbouring and similar firms often seem large and anomalous, and it is difficult to see how they could have arisen or what purpose they serve. It will be shown, however, that for collieries at any rate it is possible to find some sort of explanation for more than half of the variation in average wages, so that the pattern was far from chaotic. It would of course be *naïf* to expect anything approaching a complete explanation of the variability of the individual units at a micro-economic level. Part of the explanation for any existing pattern of wages must lie buried in the past, because wage structures are notoriously rigid and therefore could never be wholly accounted for by reference to current factors.

The main conclusions which emerge from the following analysis are that three factors each played an important and independent role in determining the average levels of wages in particular collieries. The first is labour productivity, measured in tons of coal per manshift;[1] since most faceworkers are paid by results, there is a simple and obvious connection between their productivity and their earnings. It is possible, however, that the piecework prices of workers in pits with difficult working conditions or low mechanisation may not always be sufficiently high to compensate them for the comparatively low output per manshift which they are able to achieve. On the other hand it seems to be generally held that the main reason why workers in pits with high labour productivity tend to earn more is simply that they work harder. It is not possible, with data of this kind, to judge how much weight should be given to each of these two by-no-means-mutually-exclusive explanations.

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[1] While, as has already been noted, the ' Colliery Profiles ' record manshifts-per-ton, the transformation to tons-per-manshift (the usual measure of labour productivity) was able to be carried out by the computer in the course of calculation. This is not a wholly satisfactory measure of productivity, since there are many different qualities of coal. On this measure, for example, anthracite pits, with their deep shafts, narrow seams and difficult working conditions generally, receive less than justice.

The second factor influencing the level of average wages is the distribution of a colliery's labour force between surface workers, coal-face workers and other underground workers. Since underground workers generally earn more than surface workers, while workers at the coal-face tend to be paid the most highly of all, the average wage for all workers in a colliery is naturally sensitive to the proportions of these workers. In other words, if the average wage for the entire colliery is regarded as a weighted average of the wages of each of the main categories, then some of the variation in average wages among different collieries must be attributed to differences in the weights. However obvious this may seem, there is no means of gauging its quantitative importance; the greater it is, the less the variation that needs to be explained by other factors.

The third factor exercising a strong influence on the average wages for a colliery is its location. There are, on average, pronounced differences between the wages paid in different parts of the country which certainly cannot be explained away in terms of corresponding regional variations in either of the two factors just mentioned, even though regional variations in productivity or in the distribution of labour are responsible for part of the observed wage differences. Genuine regional differences in wages have presumably to be attributed to past or present differences in the labour markets in the various areas. In general, there is a tendency for wages to be lower in predominantly mining areas where there are few alternative employment opportunities in the immediate vicinity and where wages in neighbouring industries are also comparatively low, though if the picture is looked at in detail there are always many exceptions to a generalisation of this kind. (The relation between wages and the supply of labour in the different coalfields will be examined in the further article already mentioned.)

As a point of departure we may forget about regional differences for the moment, and consider the regression of average earnings per manshift on faceworkers' output per manshift, on the ratio of faceworkers to total underground workers, and on the ratio of surface workers to underground workers, for all the 710 collieries included in this study.[1] The following regression equation is obtained:

$$\begin{array}{llr} & & \bar{R}^2 \\ (1)\ \mathrm{EMS} & = \underset{(0.88)}{35.65} + \underset{(0.10)}{1.46}P + \underset{(1.26)}{11.26}F - \underset{(1.54)}{12.17}S & 0.30 \end{array}$$

where EMS = average earnings per manshift, in shillings,

P = faceworkers' productivity, in tons of output per manshift,

F = the ratio of faceworkers to total underground workers,

S = the ratio of surface workers to total underground workers, and

$\bar{R}^2$ = the squared multiple correlation coefficient corrected for degrees of freedom. Standard errors are given in brackets below the corresponding regression coefficients.

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[1] It should be noted that these ratios have ' total underground workers ' and not ' total workers employed ' as their denominators—simply because they appear in this form in the ' Colliery Profiles '.

It will be seen that faceworkers' productivity is used in preference to overall productivity in this regression. The main reason for this is that overall productivity is affected by the distribution of labour between faceworkers, other underground workers and surface workers, and not only by the actual average output per manshift achieved by the workers at the coal-face. Furthermore, faceworkers are in general the only workers to be paid by results.

The value of $\bar{R}^2$ shows that 30 per cent of the variance of average earnings per manshift between collieries is to be explained by differences in labour productivity and in the distribution of colliery labour. Productivity is the most important of the variables in explaining wages when allowance is made not only for the size of the regression coefficients but also for the amount of actual variation from pit to pit in productivity and in the distribution of labour. Thus, although in the units of measurement chosen for equation (1) the regression coefficients for the proportions of faceworkers and surface workers are roughly ten times larger than that for productivity, the standard deviation of productivity is roughly fifteen times larger than those of the other variables. A difference in faceworkers' productivity between two collieries equal to twice the standard deviation of productivity would lead to an expected difference of 3.3 shillings in their average earnings according to equation (1), whereas analogous differences in proportions of faceworkers or surface workers would lead to expected differences in average earnings of only 1.9 and 1.7 shillings respectively.[1]

Because equation (1) is based on a cross-section of the industry in a particular year, it should not be interpreted as meaning, for example, that an increase in output per manshift of one ton on the part of the faceworkers in a particular colliery would merely increase average wages for the pit by 1.46 shillings, the coefficient of the productivity term. An increase of one ton in faceworkers' productivity would, of course, be a substantial improvement when the average for the entire industry is only just over three tons (1954). What equation (1) really implies is that pits where faceworkers' productivity exceeds that in other pits by one ton also have wages which are 1.46 shillings higher, *on average*, than in the other pits, allowing for the effects of differing proportions of faceworkers and surface workers. From this result very little can be inferred about the effect on wages of a change in productivity within a single colliery. In general, it is extremely difficult to predict the likely effects of changes occurring within any single colliery on the basis of relationships observed to hold for different collieries at a particular point of time.

Having considered the relationship between wages and productivity and the distribution of labour on a national basis, we have now to examine whether this relationship is uniform or whether it varies from one part of the country to another. Any choice of districts is bound to be somewhat arbitrary, but the accepted 'wages districts' (the traditional units for negotiation in the

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[1] To attempt to assess the relative importance of the explanatory variables in a regression is not very satisfactory if the explanatory variables are themselves appreciably correlated. A range of twice the standard deviation centred on the mean of a variable usually takes in about two-thirds of the observations.

TABLE II

District Averages of Wages, Productivity and Distribution of Labour in 1954

Wages district	*No. of pits*	*Average earnings per man-manshift (s.)*	*Average tons per manshift:*		*Distribution of labour:*	
			all workers	*face workers*	*ratio of surface workers to underground*	*ratio of face-workers to underground*
Scotland	158	42.7	1.11	2.65	0.23	0.51
Northumberland ...	53	43.7	1.22	3.30	0.25	0.46
Durham	114	42.2	1.04	2.81	0.25	0.45
Yorkshire	108	43.3	1.43	3.68	0.26	0.48
Lancashire	58	41.1	1.12	3.06	0.24	0.45
Nottinghamshire ...	35	47.8	1.87	4.80	0.25	0.52
North Derbyshire ...	30	48.0	1.84	4.52	0.23	0.51
North Staffordshire	20	40.5	1.31	4.25	0.34	0.43
East Wales[1] ...	93	39.6	1.01	2.25	0.21	0.54
West Wales[1]... ...	41	43.8	0.76	1.88	0.22	0.51
All districts	710	42.7	1.20	3.08	0.24	0.49

[1] Wales, a single wages district, was originally split into two because it was too large to be coped with by the computer programme. Although this difficulty was overcome, the split was retained since it seemed reasonable to perpetuate the separation of the anthracite pits which are mainly found in west Wales.

industry) would seem to be operationally the most useful in this context. The wages districts covered by our analysis are accordingly listed in Table II, which shows the numbers of pits in question and the average levels of wages, productivity and labour distribution obtaining in these districts in 1954. The most striking features are the high wages and productivity in Nottinghamshire and North Derbyshire compared with those in all other districts.

In order to see how far the relationship observed on a national basis holds within individual districts, the obvious procedure is to calculate the same regression separately for each district. The resulting partial regression coefficients are tabulated in Table III. In general, the results suggest a fairly consistent pattern, though one or two peculiarities are revealed. In West Wales, average wages tend to be highest in the pits with the lowest faceworkers' productivity; but this group of pits is exceptional, consisting as it does mainly of small pits mining anthracite—for which, as has been noted, a simple physical measure of productivity is not satisfactory when comparisons are being made with other groups. However, in Wales generally (and also in Lancashire) the correlations are comparatively weak. In other areas between 30 and 50 per cent of the variance of average wages can be attributed to the factors included in the regressions.

It can easily be shown that the separate regressions for individual districts give a significantly better fit to the data than the single national regression; this implies that the former regressions are not homogeneous. The appropriate statistical test is set out in the form of an analysis of variance in Table IV. The sum of squares attributable to the single national regression[1] is

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[1] That is, the sum of the squares of the deviations from the national mean of the 'expected' values of average wages yielded by the regression equation.

TABLE III

Partial Regression Coefficients from Separate District Regressions

(Colliery average wages as dependent variable)

	Partial regression coefficients of wages on:				
District	*face-workers' productivity (tons per manshift)*	*ratio of surface workers to under-ground*	*ratio of face-workers to under-ground*	*Constant term*	$\bar{R}^2$
Scotland	0.88*	−10.97*	13.79*	35.8	0.32
Northumberland ...	1.12*	−18.38*	14.54*	38.0	0.41
Durham	1.28*	− 4.93	14.85*	33.1	0.29
Yorkshire	0.95*	−19.88*	11.68*	39.3	0.43
Lancashire	1.17*	− 3.04	8.75*	34.3	0.13
Nottinghamshire ..	0.85*	−14.05*	14.17*	39.9	0.34
North Derbyshire ...	0.39	−31.60*	5.13	50.9	0.50
North Staffordshire ...	1.16*	−15.56*	−1.89	41.7	0.30
East Wales	0.97*	− 3.40	0.26	38.0	0.04
West Wales	−1.40*	−10.64	3.69	46.9	0.11
All districts	1.46*	−12.17*	11.26*	35.7	0.30

* A coefficient which is greater than twice its own standard error.

shown in the table to be 2,142 as compared with the total sum of squares of deviations about the national mean of 7,172; the ratio of these two sums of squares (adjusted for degrees of freedom) gives the square of the multiple correlation coefficient. The corresponding sum of squares for all ten district regressions together is 4,319, or more than twice that for the single national regression; the implicit squared multiple correlation coefficient, adjusted for degrees of freedom, is 0.60. Now although the fitting of separate regressions for individual districts requires an extra 36 parameters (or uses up an extra 36 degrees of freedom) as compared with a single national regression, the ensuing improvement in fit or degree of explanation is so great that it hardly needs a conventional statistical test to assure us of its significance when dealing with so many observations.[1] The implicit $\bar{R}^2$ of 0.60 for the ten district regressions together is, incidentally, the maximum amount of explanation achieved in this study of the inter-colliery variation of average wages. Although it requires no less than 39 parameters to achieve this, generically the explanation involves no more than the three basic factors mentioned. It is evident therefore that the pattern of average wages was far from being haphazard.

The fact that the separate district regressions yield such a greatly improved fit to the data shows that location, as might be expected, must have exerted a considerable influence on wages—either directly, or through differences from one district to another in the effects on wages of productivity or distribution of labour. Although it is established that some of the regressions differ significantly from each other, it is important to discover whether this

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[1] The appropriate F ratio of 14.2 (=60.47/4.26) is, of course, highly significant with 36 and 670 degrees of freedom for the two mean squares.

TABLE IV

Analysis of Variance for Regressions Listed in Table III

Due to:	*Degrees of freedom*	*Sum of squares*	*Mean square*
National regression	3	2142.3	
Difference	36	2176.8	60.47
Separate district regressions	39	4319.1	
Residuals within districts	670	2853.0	4.26
Total	709	7172.1	

is mainly due to differences in the regression coefficients (or in the slopes of the regression planes) or to differences in the constant terms (or in the positions of the regression planes). The latter case is much simpler conceptually since it implies a parallel displacement of the regression plane from district to district so that the effect on wages of being located in a particular district can be represented by a single term which combines additively with the effects of the three numerical variables considered. The next step, therefore, is to test whether the individual district regressions yield between them a significantly improved fit over a regression in which only the constant term is allowed to vary from district to district.

The problem is to fit a regression in which the coefficients of productivity and the proportions of faceworkers and surface workers are the same in every district but the constant term varies from district to district. The solution is to introduce a series of so-called ' dummy ' variables, one for each district, which are restricted to the values one and zero. In an ordinary regression, the constant term can be regarded as the coefficient of a dummy variable which always takes the value unity for each observation. We now drop this single dummy variable and introduce ten more, each one of which assumes the value unity for all the observations in a particular district, but assumes the value zero for all other observations. In this way we are able to quantify the effect of location, which in itself is a non-numerical variable. In effect, we have ten constant terms instead of one; that is, an additional nine parameters.[1]

The regression coefficients for the national regression, including the ten dummy district variables simultaneously with the three numerical variables, are given in Table V. Just as the value of the constant term in an ordinary regression usually has no particular meaning in itself—being merely the value of the intercept of the regression plane with the axis of the dependent variable when each of the other variables takes the (usually irrelevant) value zero—so the size of each of the coefficients of the dummy variable has in itself no particular meaning. It is the differences between the various coefficients of the dummy variables, or ' fitted constants ' as they are often called, which

[1] For a discussion of the use of dummy variables in regression analysis see T. P. Hill: 'An Analysis of the Distribution of Wages and Salaries in Great Britain ', *Econometrica*, July 1959; and also D. B. Suits: ' Use of Dummy Variables in Regression Equations ', *Journal of the American Statistical Association*, Dec. 1957.

TABLE V

Partial Regression Coefficients for the National Regression Equation with Dummy District Variables

(Colliery average wages as dependent variable)

Faceworkers' productivity (tons per manshift)	0.80
Faceworkers as a proportion of underground workers	9.89
Surface workers as a proportion of underground workers	−12.09
Scotland	38.3
Northumberland	39.6
Durham	38.5
Yorkshire	38.7
Lancashire	37.1
Nottinghamshire	41.9
North Derbyshire	42.1
North Staffordshire	37.0
East Wales	35.0
West Wales	39.9

$\bar{R}^2=0.55$

are important; these measure the displacements from district to district in the regression planes spanned by the three numerical variables. In other words, the differences between the fitted constants indicate the expected differences in average wages between pits in different districts—given that the pits have the same productivity and distribution of labour.

A comparison between the fitted constants (Table V) and the actual average wages for pits in the various districts (Table II) reveals only one point of much importance, namely that the expected difference in wages between pits in Nottinghamshire and North Derbyshire and those elsewhere is generally about two shillings less than the difference in average wages actually found to exist between pits in these two districts and the rest of the country. The main reason for this is undoubtedly the fact that productivity is very high on average in these two districts. Because high productivity leads to high wages, a group of pits with high productivity on average would obviously, *ceteris paribus*, have higher average wages than other groups of pits. Nottinghamshire and Derbyshire do have high productivity *vis-à-vis* other districts, but they also have high wages anyway, irrespective of productivity. Thus (for example) whereas the actual difference in average wages between these two districts and the next two highest wage districts, namely West Wales and Northumberland, was approximately four shillings, the expected difference for pits with the same productivity and distribution of labour was only two shillings according to the fitted constants. A simple comparison between average wages in Notts. and Derby and elsewhere tends, therefore, to give an exaggerated impression of their relative wage advantage, since it fails to take account, among other things, of the fact that workers in these districts, for one reason or another, produce more coal per manshift than elsewhere.

Mainly because of the reduced lead of Nottinghamshire and North Derbyshire over other districts, the differences between the fitted constants indicate that the effects of location on wages are less important than actual wage levels would suggest. About 42 per cent of the variance of inter-colliery wages can be ascribed to district differences,[1] but some of these differences are related to corresponding district differences in productivity (and to some extent in distribution of labour). If the fitted constants are used instead of the actual differences in average wages among the districts to calculate a ' between districts ' sum of squares, it turns out that only 31 per cent of the variance of inter-colliery wages can be ascribed to district differences. Thus it can be said that roughly a quarter of the actual differences in average wages between districts can be attributed to differences in productivity or distribution of labour.

Another way of summarising these results is to say that actual differences in average wages between districts provide biassed estimates of the effects of location on wages. Because districts differ on average in respect of productivity and (to a lesser extent) distribution of labour, this means that when districts are represented by dummy variables some of them are correlated with productivity and the distribution of labour. Because productivity and the distribution of labour influence wages, their omission introduces some spurious correlation between wages and districts. Conversely, therefore, it follows that the first equation—a national regression of wages on productivity and distribution of labour which omits the district variables—must also have some biassed regression coefficients. This could in fact be surmised from a systematic comparison between the coefficients for the individual district regressions given in Table III and those given in equation (1) above. In every single district the coefficient for faceworkers' productivity is less than the corresponding national estimate; indeed, the latter is almost twice the average of all the district figures. On the other hand, the coefficient for faceworkers' productivity in the national regression including dummy district variables is only about a half of that in the original national regression and is therefore close to the average of the separate district estimates.

The reason why the coefficient for faceworkers' productivity in equation (1) seems to have an upward bias is that pits in Notts. and Derby, which have high productivity, also tend to have high wages irrespective of productivity. The national regression without dummy district variables is unable to distinguish between the effects of district and the effects of productivity and hence tends to attribute the high wages in Notts. and Derby entirely to the high productivity; and it is this which seems to account for most of the upward bias.

The coefficients of faceworkers' productivity in the national regressions with and without dummy district variables are 0.80 and 1.46 respectively so that the difference between them is very large compared with their standard errors which are only 0.11 and 0.10 respectively. It seems, therefore, that the bias involved in omitting to take account of the effects of location is much greater than any conceivable sampling error. This result is probably typical of most attempts to estimate economic relationships when investigators are unable to take explicit account of all the more important factors through lack of data. The present example is merely one illustration of this and shows, in particular, the futility of trying to estimate at a national level the form of a relationship which itself varies between different parts of the country. More often than not, however, the investigator will not be in the fortunate position of being able to take account of location in the way that was possible with the data and computing facilities available to us.

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[1] The figure of 42 per cent is obtained by partitioning the total sum of squares for colliery wages into a ' between districts ' and a ' within district ' sum of squares by an ordinary analysis of variance. This is equivalent to saying that the value of $\overline{R}^2$ for a multiple regression of wages on the ten dummy district variables alone, *excluding* the three numerical variables, is 0.42.

The question of whether or not the effects on wages of productivity and of the distribution of labour themselves differ significantly from district to district has next to be considered. In other words, it has still to be established whether there is any ' interaction ' between the numerical variables and the dummy district variables. The appropriate statistical test can again be presented in the form of an analysis of variance, which amounts to examining whether the additional explanation achieved by the ten separate district regressions listed in Table III is significantly greater than that achieved by the single national regression including the ten dummy district variables, allowing for the much greater number of parameters required (or degrees of freedom used up) by the individual district regressions. As mentioned above, the national regression with dummy district variables permits parallel displacement from district to district of the regression plane spanned by the numerical variables, but does not permit any variation in the slope of this plane between districts. When completely separate regressions are fitted for each district some variations in the slope of the regression plane are, of course, found from district to district; but the question arises whether or not these variations are significant.

TABLE VI

Analysis of Variance for Regressions Listed in Tables III and V

Due to:	*Degrees of freedom*	*Sum of squares*	*Mean square*	*F ratio*
National regression	3	2142.3		
Difference	9	1843.3	204.8	
National regression with dummy district variables	12	3985.6		
Difference	27	333.5	12.35	2.90
Separate district regressions	39	4319.1		
Residuals within districts	670	2853.0	4.26	
Total	709	7172.1		

The analysis of variance needed to answer this question is shown in Table VI; the analysis is, in fact, an augmented version of that presented in Table IV. The conclusion which emerges from the analysis is that the improvement in fit achieved by the ten individual district regressions taken together over the national regression including dummy district variables is small but significant. The value of $\bar{R}^2$ for the national regression with dummy variables is

0.55, whereas the corresponding figure for the ten district regressions in combination is 0.60 as already stated; the difference between them is clearly significant in view of the large number of observations included in the analysis.[1] Nevertheless it will now be argued that, although the improvement in fit is 'significant' in the conventional statistical sense, it is so small as not to justify the additional complications introduced by having ten separate regressions as against a single regression with dummy variables.

All that the statistical test establishes is the *existence* of some differences among the regression coefficients for the various districts; in other words, that at least some of the inter-district differences in the regression coefficients listed in Table III are too large to be ascribed to chance. The results of the test certainly do not imply that all or even the majority of the differences are significant. Moreover, with so many observations as there are here, the existence of quite small or unimportant differences will be established by the test. It seems, therefore, that the main usefulness of the analysis of variance shown in Table VI is not that it enables a routine test of significance (or existence) to be carried out, but that it reveals in an objective manner exactly how much the fit is improved by using separate district regressions. The total sum of squares of the expected values from the regressions increases merely from 3,986 to 4,319, or by one-twelfth, when separate regressions are fitted instead of a national regression with dummy variables. However, the number of parameters required is more than trebled, increasing from 12 to 39. On the principle of Occam's razor, therefore, the fitting of separate regressions hardly seems to be justified, even though it is known from the significance test that not all the parameters are exactly the same in every district.[2] Accordingly, it seems reasonable to conclude that the single national regression with dummy variables provides an adequate description of the data in a convenient summary form and that the improvement in fit obtained by using separate regressions is not nearly large enough to offset the loss in theoretical simplicity.

Inspection of the estimated coefficients listed in Table III strongly suggests that the villain of the piece is the negative coefficient for faceworkers' productivity in West Wales, which is evidently significantly different from the corresponding coefficient in most other districts.[3] This does not imply that there are no significant differences between any other districts in any of the three regression coefficients, but the negative coefficient for faceworkers' productivity in West Wales is clearly the most exceptional feature of the data in Table III.

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[1] The F ratio for the two relevant mean squares needed to test the significance of the improved fit obtained by using separate regressions is 2.90 (see Table VI). The probability of obtaining by chance a ratio as large as this is well under 1 per cent according to the F distribution when there are 27 and 670 degrees of freedom for the two mean squares.

[2] Entia non sunt multiplicanda (Occam): '. . . for the purposes of explanation things not known to exist should not, unless it is absolutely necessary, be postulated as existing' (Shorter O.E.D.). Παραμετρητέον ὡς ἐλάχιστα.

[3] If West Wales were excluded from the analysis altogether, it is probable that the relative improvement in fit of the separate district regressions over the national regression with dummy district variables would be considerably reduced, perhaps to the point of non-significance. It was not considered worth while, however, to recalculate the national regression with dummy variables excluding West Wales (which would be an extremely lengthy business) merely in order to test this particular hypothesis.

The main conclusion to be drawn from the analysis of this section is that the variability of average wages among different pits was very far from being haphazard in 1954: well over half of it could be associated with differences in productivity, location and the distribution of labour. Given the rigidity over time of most wage structures, it is doubtful whether much more than half of the dispersion of wages between different firms is ever likely to be explained in terms of current values of related variables anyway. Indeed, the insensitivity of the pattern of colliery wages in 1954 to changes during the previous three years can be illustrated by the regression of the current level of average wages on change in wages over the preceding three years. The regression coefficient is close to unity, as would be expected,[1] but the squared correlation coefficient was only 0.22; in other words, less than a quarter of the variance of colliery wages in 1954 could be attributed to changes in wages during the previous three years. Somewhat surprisingly, there seems to be virtually no relation whatsoever between changes in wages and changes in productivity or in employment, the squared multiple correlation coefficient for all three of these variables being 0.005.[2]

Apart from the relation between average wages and productivity, location and distribution of labour, the only other factors which might possibly have some effect on wages seemed to be non-wage costs and the size of the colliery. However, the inclusion of both of these variables together in the national regression with dummy variables listed in Table V merely increased $\bar{R}^2$ from 0.548 to 0.554 without materially affecting any of the other regression coefficients, so that their inclusion in the main analysis was not felt to be justified.[3] The slight positive (partial) association between wages and non-wage costs might be interpreted as meaning that highly mechanised pits are better able to afford to pay high wages; but this interpretation is not very satisfactory when labour productivity is explicitly included as one of the other explanatory variables in the same regression. Furthermore, it is difficult to see why wages should tend to increase slightly as the size of the colliery increases except as a result of the effect of some other unobserved variable or variables which

[1] The coefficient is actually 1.11 and the fact that it is greater than unity implies that the dispersion of colliery wages must have been increasing slightly during the previous three years—a tendency which was presumably reversed in 1955 when the revision of the wage structure for timeworkers was begun by the National Coal Board.

[2] The fact that changes in wages and changes in employment are completely uncorrelated does not, of course, mean that differences in wage *levels* do not affect labour turnover.

[3] Their exclusion was also based on the principle of Occam's razor and not on their lack of statistical ' significance ': both the partial regression coefficients are significantly different from zero, but so small as to be trivial; the partial regression coefficient of average wages on non-wage costs (measured in shillings per ton of output) is 0.03 while the coefficient of colliery size (measured in terms of employment) is 0.0003.

are correlated with size. Both associations are extremely weak but also, possibly, partly spurious.

Although the main analysis above has been successful in accounting for a large part of the variability of wages between collieries which existed in 1954, it does not throw much light on the economic forces which generated this particular pattern of wages. To the extent that any wage structure represents a gradual accumulation of wage differences over many years, the type of analysis carried out here may be only partially successful. Thus district variations themselves (which account for nearly a third of wage differences after discounting for productivity and structure of labour force), are in a sense the alluvium of history, for regional differences in respect of labour markets do not arise overnight. Nor for that matter does the structure of the labour force, which determines the prevailing proportions of highly paid workers. Even productivity differences are by no means independent of past influences—although these, together with their effects on wages, are more likely to be affected by current changes than either of the other variables. These three between them, however, in accounting for more than half the wage variation between collieries in 1954, suggest a remarkable degree of order—even if not of wholly adequate explanation—in the diversity.

APPENDIX

Profits and Wages

One of the associations which seemed to be worth pursuing was the weak correlation ($\bar{r}^2=0.005$) between wages and profits—a possible hypothesis being that the profitability of pits might affect the wages paid. But the reason for the slight positive association between the two is that both are strongly affected by productivity; and at any given level of productivity there is a marked negative association between wages and profits. It looks therefore as if the relationship which we are observing is merely that profits, as an accounting residual, must vary inversely with wages *ceteris paribus*. This in turn implies that it is profits that has to be taken as the dependent variable.

The multiple regression of profits on wages and labour productivity is as follows:

$$\begin{array}{llr} & & \bar{R}^2 \\ (2) & \pi = \underset{(6.44)}{40.88} - \underset{(0.17)}{2.09}\ \text{EMS} + \underset{(1.30)}{37.27}\ P & 0.54 \end{array}$$

where π = profits in shillings per ton,
EMS = average earnings per manshift, and
P = average output her manshift in tons.

On average, the pits included in this study were making a loss of 3.85 shillings per ton.[1] One implication of the regression is thus that, if a pit were paying the average wage of 42.72 shillings, its output per manshift would have needed to exceed the national average by 0.103 tons (or just under 10 per cent) for the pit to break even. Another is that, if a pit's productivity were equal to the national average, it would have needed to pay 1.84 shillings per manshift less than the national average in order to break even. (Since these generalisations are based on relationships between averages, they need not necessarily apply to every pit.)

TABLE VII

Partial Regression Coefficients for National Regression Equation with Dummy District Variables

(Colliery profits as dependent variable)

Average earnings per manshift	—1.40
Average output per manshift in tons	36.06
Scotland	10.14
Northumberland	12.71
Durham	17.80
Yorkshire	14.63
Lancashire	12.66
Nottinghamshire	5.98
North Derbyshire	6.68
North Staffordshire	12.53
East Wales	18.24
West Wales	2.22

$\bar{R}^2 = 0.59$

When allowance is made for possible district variations of this relationship by including the ten dummy district variables in the regression, then the effect of wage differences on profits is considerably reduced (see Table VII); the partial regression coefficient for productivity, on the other hand, is virtually unchanged. But the interesting result revealed by the coefficients listed in Table VII, however, is that, given the level of productivity and wages, expected profits are lower in Nottinghamshire and North Derbyshire than anywhere else except West Wales, despite the fact that actual profits were highest in these two districts. The explanation for this paradox is simply that their average output per manshift was so high that the downward pressure on profits exerted by high wages was far more than offset. It is beside the point to argue that these two districts would be relatively unprofitable had productivity there been no higher than the national average, when in fact it was about 50 per cent higher. The proper inference seems to be that, in general, pits outside Notts. and Derby with comparably high productivities tended to be more profitable.

It is not easy to see why the coefficient of wages is reduced by the inclusion of dummy district variables, but one contributory factor is that average wages in West Wales—the district where profits are lowest—are somewhat above the national average. The national regression without dummy district variables tends to attribute the losses made in West Wales to the high wages there without allowing for the fact that profits are low in West Wales compared with pits with similar wage levels elsewhere. However, the situation is greatly complicated by the further fact that output per manshift is also very low in West Wales and that, as has already been shown, it is negatively correlated with wages there. Whatever the explanation of the change in the coefficient of wages caused by the introduction of the dummy variables, the change is again sufficiently large to illustrate the pitfalls of estimating relationships on a global basis.

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[1] This is again an unweighted mean for all the 710 pits: according to the N.C.B. published accounts for 1954, the industry as a whole made a profit of 1s. 7d. per ton. The difference between the two statistics is reconciled by the fact that larger pits tended to show greater profits (or smaller losses), although there is also some difference in coverage between the two averages.

INDIA'S BALANCE OF PAYMENTS

By G. D. A. MacDougall

(This article appeared in *The Economic Weekly*, Bombay, April 22nd and 29th, 1961, and is reproduced, with a few modifications and omissions, by kind permission of the Editor. It should be borne in mind that it was addressed to an Indian audience. Rs. 1 crore = 10,000,000 Rupees = £750,000)

I. The Problem

It is arguable whether the balance of payments is *the* most important factor limiting the rate of India's economic development, but it will probably at least be agreed that it is *a* major limiting factor. Shortage of foreign exchange is certainly holding up production quite seriously at present and there is a danger that it will continue to restrict output and the rate of growth during the Third Plan and, looking further ahead, in the Fourth and the Fifth.[1]

The present situation

Many factories are to-day lying partially idle through lack of imported supplies. A glance at Table I shows unused capacity over a wide field, even on a single shift basis, and rather few industries working multiple shifts. One-third of the industries covered appear to be working at only 60 per cent of capacity or less. (The data refer to the year 1959–60, but it seems unlikely that there has since been any general improvement; output has increased, but so has capacity. The figures may sometimes overstate capacity for statistical reasons; on the other hand, the table relates production to capacity at the beginning of the year so that the percentages of capacity utilised would often be still lower if account were taken of new capacity installed during the year.)

There are, of course, many reasons other than shortage of foreign exchange for this state of affairs. New factories inevitably have teething troubles; short runs and breakdowns interrupt production even in established factories; capacity may have been installed in excess of current needs where demand is expected to increase; demand may sometimes have been over-estimated; and so on. But a substantial part of the unused capacity undoubtedly reflects shortage of imported materials, components, spare parts and replacements. This is true, for example, of a good many industries using steel, non-ferrous metals, wood pulp, rubber, and intermediates for certain chemicals and drugs; factories in many fields are held up for lack of vital bottleneck items; some firms that have agreed to a 'phased programme' of reducing the import content of their production (imposed quite properly to induce progressive import-saving) have fallen behind schedule and are unable to get the imports required for full production.

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[1] The Third, Fourth and Fifth Plans cover the five-year periods beginning April 1st, 1961, 1966 and 1971.

TABLE I

Utilization of Manufacturing Capacity

Production during year 1959–60 as per cent of installed capacity at beginning of year in 121 industries

	Basis of capacity figures:		
Production as per cent of capacity: [1]	*2 or 3 shifts*[2]	*1 shift*	*Total*
		Number of industries	
Over 150	1	4	5
,, 100, not over 150	7	16	23
,, 90 ,, ,, 100	4	7	11
,, 80 ,, ,, 90	7	10	17
,, 70 ,, ,, 80	4	6	10
,, 60 ,, ,, 70	—	15	15
,, 50 ,, ,, 60	—	10	10
,, 40 ,, ,, 50	2	15	17
,, 0 ,, ,, 40	2	11	13
Total	27	94	121

[1] It is assumed that plants work 300 days in the year, or 330 in some of the three-shift industries.

[2] Including some industries on continuous operations, with allowance for shut-downs for normal repairs and maintenance.

Source: *Monthly Statistics of the Production of Selected Industries of India.*

It seems likely that, say, a further Rs. 100 crores per annum could usefully be imported to meet industry's requirements, given the present level of demand for industrial goods, and that this might increase industrial production by perhaps 15–20 per cent, or by several times the value of the increase in imports. Shortages of home produced goods and services, such as coal, power and transport, might limit production in certain fields, but these too could sometimes be overcome by imports, at least after a time, were foreign exchange available. Imported oil, for example, might be substituted for coal in coastal regions, and at the same time save transport, while generating plants to be run on oil or water power might be imported to relieve the power shortage.

Industrial production might be further increased if still more foreign exchange were available for imports of materials, etc.; for effective demand might then be allowed to increase with less fear of inflation, since some extra supplies would be forthcoming to meet the extra demand.

Increased imports of fertilisers could likewise increase the value of agricultural output by a multiple of the foreign exchange cost. A still further substantial increase in national production and employment might be possible if large scale public works were undertaken, using under-employed labour and indigenous materials, and if the extra demand of the workers employed could be met by increased imports. (Mr. Andrew Shonfield recently suggested that such imports, at least of foodgrains and perhaps of cotton, might be obtained from the U.S. as a free gift, in addition to what is already being imported under Public Law 480.)

In these various ways, shortage of foreign exchange is a serious bottleneck holding up production and preventing anything like the full use of the nation's industrial capacity, land and labour. Increased aid or exports could make possible an increase in production several times as great in value and, by raising income, raise savings and investment and thus the rate of economic development.[1]

The Third Plan

Shortage of foreign exchange will continue during the Third Plan and there is a serious danger that it will make impossible the rate of development that is hoped for and that is absolutely essential. Even if foreign aid is forthcoming on the large scale envisaged in the *Draft Outline* of the Third Plan (more than twice that received in the Second Plan), this may not be enough; for the import needs seem to have been substantially under-estimated, as they were in the Second Plan.

The allowance for ' development ' imports[2] implies a very rapid increase in the output of capital goods in India, and any estimate of requirements probably tends to under-state the ancillary and unforeseen types of equipment that have to be imported. The growing tendency for aid to be tied to exports from the aid-giving country, especially the United States, will increase the cost. There is no guarantee that the prices of capital goods generally will not rise in the aid-giving countries, as they have done in the past.

The allowance for ' maintenance ' imports (including capital goods for replacement) looks very low. The average for the Third Plan is put at little more than Rs. 700 crores per annum.[3] This is probably no more, and perhaps less, than the present rate of importation which is severely restricted and, as we have seen, quite insufficient for the proper maintenance of the economy. Import needs, moreover, seem likely to grow despite the large increase planned in import-saving production, if, as is contemplated, industrial output is to grow by about two-thirds over the next five years and national income by something approaching one-third.[4]

There is also the special problem of getting aid for ' maintenance ' imports; aid-giving countries usually prefer to finance imports of capital goods for ' projects ' that will create monuments to their generosity, though there are welcome signs that this attitude is changing. India is probably in rather an unusual position among under-developed countries in that the foreign aid required to supplement her domestic savings tends to exceed her needs for imported capital goods for new investment; for she is an important producer of capital goods. Part of the aid is thus required for maintenance imports.

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[1] The following very simple example shows how extra exports may increase savings and and investment. It ignores many complications. The figures are purely illustrative.

Curtail home consumption of, say, bicycles by Rs. 100.
Increase exports of bicycles by Rs. 100.
Import Rs. 100 extra raw material.
Put Rs.75 into production of consumption goods and make an extra Rs. 300 of consumption goods.
Put Rs. 25 into production of capital goods and make an extra Rs. 100 of capital goods.
Extra income (wages and profits) is Rs. 225 in consumption goods production, Rs. 75 in capital goods production, total Rs. 300.
Say, one-third of this is taxed or saved, i.e. Rs. 100. This finances the extra output of capital goods. Consumption demand out of the extra income goes up by Rs. 200 and this is met by the extra production of consumption goods of Rs. 300, less the fall in purchases of bicycles of Rs. 100.

[2] Capital goods for new investment together with components, etc. for increasing production of capital goods in India.

[3] Rs. 3570 crores over the five years. *Third Five Year Plan—A Draft Outline*, page 53.

[4] See *Draft Outline*, pages 31 and 228.

There is not necessarily anything improvident about taking aid for such imports. It can help to increase investment just as much as aid to finance new capital goods. A large part of the Marshall Aid given by the U.S. to Europe was in fact used to finance imports other than of capital goods.

(Even if more aid were made free to spend on either maintenance or development imports, there would remain a problem of how much to switch to the former to ' feed ' existing unused capacity. For some of this would produce relatively inessential goods—a legacy of unduly liberal licensing of capacity for such goods in the past.)

India enters the Third Plan, faced with all these difficulties and uncertainties, with no cushion against unforeseen contingencies as there was at the start of the Second Plan. Foreign exchange reserves cannot be drawn upon to any significant extent—they are a small fraction of what they were five years ago—and there are few remaining inessential imports to be cut.

For all these reasons, it seems unlikely that the Plan can be achieved unless aid, or India's exports, or both, are very substantially increased above the levels contemplated in the *Draft Outline*. If more aid is not received—and I think it should certainly be asked for—exports would probably have to be increased by nearly one-half during the next five years. Even this would leave a very difficult position during the earlier years, because exports cannot be increased overnight and some of the more important import-saving investments will bear fruit only in the later years of the Plan.

The Fourth and Fifth Plans

Even if more aid, including aid for ' maintenance imports ', can be obtained in the Third Plan, this should not in any way weaken the export drive. It will still be necessary to aim at an increase approaching one-half in exports during the next five years to provide a base for the further massive increase that will be needed during the Fourth Plan if India is to achieve independence of foreign aid, and yet maintain rapid growth, in the Fifth. This would probably involve exports at the beginning of the Fifth Plan of as much as Rs. 1500 crores per annum, more than twice the present rate of under Rs. 650 crores.

Such a very large increase may come as a shock to some readers and it requires some justification. I cannot give a detailed proof; this would require much further study, and I hope that others will attempt such a calculation. But I believe that an increase of the order mentioned can be shown to be plausible and indeed the minimum required. In brief, exports two-thirds higher are needed merely to pay for present imports; it seems inevitable that more imports will be needed in ten years to maintain the much higher activity it is hoped to achieve; heavy repayments of capital and interest will fall due on loans already received and that will be received during the next ten years.

A rather fuller justification will now be attempted. (Table II will help readers to understand some of the figures mentioned.)

'*Maintenance*' *imports*[1] at present seem to be around Rs. 700–750 crores per annum and should be nearer Rs. 850 crores to allow industrial capacity to be more fully used. If it is hoped to raise national income by over three-quarters, and to treble industrial production, by the beginning of the Fifth Plan—this would be merely a continuation of the growth rates implied in the Third Plan,[2] and an acceleration is really needed—it is hard to see how maintenance imports could be kept below, say, Rs. 1000 crores at the very least, despite a rapid development of import-saving activities. This would mean that the increase in maintenance imports (Rs. 250–300 crores) was only about 2½ per cent of the increase in national income.

I should have put down a larger increase, had it not been for the view implied in the *Draft Outline* that maintenance requirements will not rise during the Third Plan. I feel that at least some modest increase must be allowed for, considering that

(*a*) there have been very few examples of countries achieving rapid development without an increase in imports (although India might conceivably provide a unique example of rapid import-saving over the the next decade);

(*b*) the present level of imports is severely restricted;

(*c*) a large expansion of exports will be very difficult unless special types of materials and equipment required to make goods acceptable abroad are imported;

(*d*) a substantial part of the expansion of exports is likely to be directed to the Soviet bloc on a bilateral basis and to some neighbouring countries on what may in effect be a bilateral basis, so that some imports may have to be accepted that would not be regarded as essential if foreign earnings were freely convertible. (In this context it is important to ensure that goods exported to Soviet bloc countries are not re-exported to other countries to replace direct exports that would have earned convertible currencies. Trade figures suggest that there may have been some diversion of this sort.)

'*Development*' *imports* in the Second Plan seem to have averaged Rs. 300–400 crores per annum and are expected to exceed Rs. 400 crores per annum in the Third Plan[3]; they may well have to be nearer Rs. 450 crores for reasons mentioned earlier. It is hard to believe that they could be less than,

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[1] Excluding food imported from the U.S. under P.L. 480 assistance.

[2] *Draft Outline*, pages 31 and 228. The rates of growth are over 5 per cent per annum in national income and about 10½ per cent in industrial production; these have been compounded over the eleven years 1960–61 to 1971–72.

[3] *Draft Outline*, page 54. Development imports are at present running temporarily at a lower figure.

TABLE II

Trade and National Income

	1960–61 estimated	*1971–72 assumed*	*Increase*	*Per cent per annum*
1. National income, Rs. crores ...	13,700	24,700	11,000	5.5
2. Imports,[1] Rs. crores	1,080	1,400	320	2.4
3. Imports, per cent of 1	7.9	5.7	2.9	..
4. Exports,[1] Rs. crores	640	1,500	860	8
5. Exports, per cent of 1	4.7	6.1	7.8	..

Year	*National income (current prices) Rs. crores*	*Imports[1] c.i.f. Rs. crores*	*% of National Income*	*Exports[1] f.o.b. Rs. crores*	*% of National Income*
1951–52	9,970	962.9	9.7	730.1	7.3
1952–53	9,820	633.0	6.4	601.9	6.1
1953–54	10,480	591.8	5.6	539.7	5.1
1954–55	9,610	683.8	7.1	596.6	6.2
1955–56	9,980	761.4	7.6	640.2	6.4
Average 1st Plan ...	9,972	726.6	7.3	621.7	6.2
1956–57	11,310	1099.5	9.7	635.2	5.6
1957–58	11,400	1233.6	10.8	594.1	5.2
1958–59	12,470	1029.6	8.3	575.9	4.6
1959–60	13,000[2]	923.7	7.1[2]	623.3	4.8[2]
1960–61	13,700[2]	1080[2]	7.9[2]	640[2]	4.7[2]
Average 2nd Plan ...	12,376[2]	1073.3[2]	8.7[2]	613.7[2]	5.0[2]

[1] Balance of payments basis. [2] Estimated.

say, Rs. 400 crores per annum at the beginning of the Fifth Plan if, as is hoped, investment is to be raised to over 2½ times the present level (11 per cent to 16 per cent[1] of a national income more than three-quarters higher, and a still higher investment ratio is really required). Merely to prevent an increase in the need for development imports will be difficult. Apart from the very large rise required in the output of capital goods *as a whole*, there is the problem of special types of equipment. At the stage of development that India will have reached there seem bound to be many types that she will still be unable to produce, especially as many new things will be developed in the world during the next decade. At Rs. 400 crores, development imports would be only 10 per cent of India's net investment (though a larger fraction of the capital goods required for net investment).

With maintenance imports at Rs. 1000 crores and development imports at Rs. 400 crores, *total imports* would be Rs. 1400 crores. This would be little more than 5½ per cent of the national income. The lowness of this figure may be appreciated when it is realised that in the United States—a large country with very diversified resources, in the van of technological progress, and with a long history of economic development behind high tariffs—imports (c.i.f.) are 4 per cent of the national income[2] (and were usually 5½ per cent or more until the 1930s). The corresponding figure for the U.S.S.R. may also be of the order of 4 per cent. Apart from China, there is virtually no other country with an import ratio anything like so low. If India's national income were valued at U.S. prices, the ratio of imports to national income assumed for the beginning of the Fifth Plan would probably be under 4 per cent.

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[1] *Draft Outline*, pages 6 and 43.

[2] 4.1 per cent in 1959. The more usually quoted figure for imports f.o.b. as a percentage of the gross national product is lower (3.2 per cent).

Although I have allowed for an increase in total imports above the 1960–61 level, and thus assumed no absolute import-saving, there would have to be massive import-saving in a relative sense. Imports would have to fall from nearly 8 per cent to little more than 5½ per cent of the national income. The increase in imports would be only 3 per cent of the rise in national income. The rate of increase assumed in the quantity of imports (2½ per cent per annum) is much less than that required by the U.S. throughout the half century ending in 1929 (about 4 per cent per annum), although the planned rate of increase in India's real national income is much higher than that achieved by the U.S. during this period.

In addition to imports, the *service of public external debt* (including interest and repayments) may well be as much as Rs. 200–250 crores per annum, even if the bulk of the loans received during the next ten years are on easy terms, and especially if repayments due in the Third Plan are postponed or covered by new borrowing, as was contemplated in the *Draft Outline* (page 55). On the other hand, *net invisible earnings* (excluding interest on the public external debt) together with net inflow of private capital may provide, say, Rs. 100–150 crores.[1] *Exports* would then have to be about Rs. 1500 crores.

It may be argued that there is no need to aim at such a high figure since foreign aid is likely to continue in the Fifth Plan. But it would seem to be rather a dangerous gamble to count on this. Political conditions can change greatly in ten years. Mr. Kennedy, for example, will no longer be President of the United States and there will be many other claimants for whatever aid is available, including many countries whose ability to use aid profitably will be much greater than it is today.

Even if it is assumed that substantial aid will be *available* to India in the Fifth Plan, this will not necessarily change the export target that should be aimed at. For if internal savings have by then been stepped up to a level that can give a satisfactory rate of growth without foreign assistance, India will presumably not wish to accept it; and it would be unfortunate if balance of payments difficulties made this necessary. If, on the other hand, internal savings are still inadequate—and it will admittedly be difficult to raise them sufficiently—it will not be hard to create a balance of payments deficit, if necessary, by stepping up the rate of investment, so that a balance of payments case for aid can still be made and the aid can be absorbed.

It is possible that there will be important discoveries of oil or other natural resources that can be used to replace imports. But it would be imprudent to count on discoveries that would have a revolutionary effect on the balance of payments until they have actually been made. In any case, such resources would take time to develop. I have, moreover, already allowed for very large scale import-saving. And a completely autarkic policy of import-saving at any cost—of producing anything that it is physically possible to produce in India—would undoubtedly slow down the rate of growth.

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[1] These items at present yield under Rs. 100 crores, net, excluding also official donations. Earnings from transportation and especially tourism should rise, as should private investment from abroad. On the other hand, there may be significant extra payments of income on such investments.

This is not to say that investment in import-saving should not have some preference—and perhaps quite a substantial one—over investment in production for export. I think it should, because, for example, of the greater dependence of exports on circumstances outside India's control and of the tendency for a pushing of exports to worsen the terms of trade. But the preference for import-saving should not be absolute. For example, an investment in production for export that required only, say, a 10 per cent export subsidy should normally, I suppose, be preferred to an investment in import-saving that required protection equivalent to, say, a 50 per cent import duty, after allowing a reasonable time for infant industries to grow up in either case.

The magnitude of the export task

For all these reasons, I feel that a target of around Rs. 1500 crores per annum for exports at the beginning of the Fifth Plan is by no means too high. It would mean, very roughly, an increase of one-half during the next five years and a further increase of one-half during the following five years. There is no point, of course, in arguing about the precise figure, for in any case it will probably be agreed that the increase required is very large indeed; but I shall use the figure of Rs. 1500 crores for purposes of illustration.

The rate of increase required would be a difficult task for any country. But it is not impossible. It has been achieved over the past decade by quite a number of countries (in addition to those exporting oil), such as Yugoslavia, Israel, Japan and a good many nations in Western Europe. But how practicable is the task for India?

From the point of view of reserving a sufficient proportion of the nation's investment and additional output for exports, the task does not look unmanageable. Exports would have to rise by 8 per cent per annum compared with an increase of 5–6 per cent in the national income. Less than 8 per cent of the increase in output would have to be devoted to exports. The proportion of the national output exported would merely have to be restored to the level achieved half-a-dozen years ago.

These figures, of course, refer to output as a whole, and there will for a time be difficult problems in particular fields where home demand will have to be restrained to make room for exports. But the pattern of output can be changed considerably over a period so that, looking ten years ahead, the problem should not be too difficult, provided an appropriate pattern of investment is adopted.

When, however, one considers the problem of selling the goods abroad, the task appears much more difficult, for India's exports would have to increase faster than world trade seems likely to expand. The latter has risen in terms of quantity by about one-third in each of the last two five-year periods (and may perhaps grow more slowly in future); exports of underdeveloped countries taken as a whole have grown considerably less quickly.

Now, while world trade has been expanding quite rapidly, India's exports have been stagnant during the last ten years (at least in value, though there has been some upward trend in quantity). This is partly because her share in the world market for certain products has been falling (sometimes mainly for external reasons, sometimes in the main because Indian domestic consumption has been catching up with production). In jute manufactures, for example, Pakistan has entered the world export market, and Thailand has entered that for lac. In tea, East Africa and Ceylon have been increasing their share of the U.K. market at India's expense. India's share in the world market for manganese ore has fallen; new competitors have been entering the field. In groundnut oil, where once she had a substantial share, her exports have now virtually dried up.

Probably the more important reason, however, why India's exports have fared so much worse than world exports as a whole is that they depend rather heavily on items where world trade is expanding only slowly, if at all. Nearly one-half of India's exports still consists of the three traditional staples—tea, cotton textiles and jute manufactures. World trade in these items taken together seems unlikely to expand very rapidly in future, barring a striking increase in imports by the Soviet bloc; and the scope for increasing India's share is limited because it is already high in tea and jute manufactures, while an attempt to expand markedly her quite substantial share in cotton textiles would be likely to provoke restrictive measures abroad. Exports of the three staples must be vigorously promoted; they are far too important to be neglected. But, while quite a sizeable increase is by no means impossible, it is clear that, to achieve the total exports required, there will have to be a really striking increase in the other items; they may well have to be trebled or more.

Now among these there are some very promising exports even outside the field of the newer manufactures. There could be rapid increases in the earnings from, for example, iron ore, coffee, fish, vegetable oils and, in the field of invisible exports, tourism. These are items where world trade should expand rapidly, or where India's share is small and could be raised substantially, or both. There is also a good number of other quite promising items.

But, even on optimistic assumptions about all these and other commodities, it would seem impossible to reach anything like the level of exports required without a very substantial contribution indeed from the newer manufactures. Exports of these must be increased many times over to several hundred crores per annum. Their present share of only about five per cent of exports must be raised to a much more important fraction.

Taking account also of the rapid expansion needed in the other promising items, it is clear that an almost revolutionary change will be required in the structure of India's export trade. When this has become more heavily weighted in favour of products where world trade is growing fast, a rapid expansion of her exports will become less difficult.

I must confess that India's export task looks extremely formidable but I do not think it need be a matter for despair, for cutting down or drastically altering the fundamental nature of the Plan, or for giving up all hope of achieving rapid growth without foreign aid within a decade. In products where India's share of the market has declined, it is by no means inevitable that this must continue or that part at least of her previous share cannot be regained, provided really vigorous measures are taken to increase production, to free supplies for export, to make them competitive, and to market them. We have seen that there are a good many exports which could be rapidly increased. In the case of the newer manufactures, it is sometimes argued that the world market will not expand very rapidly in future because of the simultaneous industrialisation of a large number of under-developed countries. But, even if this is true—which is doubtful—it might still be possible for India to carve out the rather small share she needs—perhaps about 2 per cent of the world export market for the relevant products as a whole—a smaller share than that of such small countries as Sweden, Switzerland, the Netherlands or Belgium.

India, too, though poorer than the great majority of under-developed countries per head of population, is more advanced industrially than most. She should thus be able, by keeping one step ahead, to sell them manufactured products that they cannot yet produce. The trading skill of Indians and the numerous Indian traders abroad should be of assistance, as should be the selling organisations and experience built up by textile exporting firms over a long period.

It is possible, too, that more and more international firms selling all over the world will, if permitted to do so, choose India as one of their bases for production and export (as some are already doing). For, among the low-wage countries, India's claims are high. She has one of the largest home markets; the general political outlook is more secure than in many other countries (although the extent of Government control may prove a deterrent); she has a good supply of educated personnel and of industrial facilities generally.

But, while there is no need for despair, the task is certainly a very difficult one indeed. What has to be done if there is to be a chance of success?

II. Conditions of Success

1. *The role of Government*

The first and fundamental requirement is a recognition of the vital need for a rapid and massive increase in exports if India's economic development is not to be seriously jeopardised, and acceptance of this fact as a major basis of economic policy.

While most of the actual exporting will have to be done by private business, the role of Government will be crucial. Some difficult decisions must first be made on general policy, involving much more drastic measures than have hitherto been taken. But these will be fruitless without really effective machinery, which can cut through conflicting departmental interests, to translate them rapidly into concrete measures, including schemes for each product, and then to take quick decisions on their day-to-day implementation and interpretation (for potential customers abroad, in a highly competitive world, will not wait for long while Indian officials make up their mind).

2. *Emphasis on economic efficiency*

If India is to compete in world markets without prohibitive subsidies, it is essential to go all out for maximum economic efficiency, and low costs, even if this conflicts with other considerations.

Where economies of scale are important, it is vital to concentrate on large plants even if this means less regional dispersion of industry, and more concentration of economic power; competition is usually good for efficiency but the deliberate creation of several undertakings where one could produce far more cheaply is unlikely to achieve the desired result. It may be tempting to give preference to smaller firms because they employ more labour; but they may be unable to compete in world markets. Larger enterprises, even if they employ fewer people directly, may, by earning foreign exchange which can be spent on scarce materials, make possible more employment in industry as a whole.

The need for exports may also conflict with the desire for fair play. For example, foreign exchange must be granted quite liberally to would-be exporters for travel and sales promotion abroad, even though this may lead to some abuse. And in so far as reliance is placed on the State Trading Corporation or other Government agencies to sell goods abroad, emoluments will have to be paid that can attract from the private sector the best experts in the various branches of trading, even if these are out of line with governmental salary scales. It will also be difficult for State traders to compete with private traders abroad if they are inhibited by the rules to which other officials, for good reasons, are subject, so that they can be called to account for each individual decision rather than for their performance as a whole.

3. *Restraints on home demand*

Consumption of exportable goods will have to be restrained where supplies are inadequate to meet both home and export demand—and even where supplies could be increased sufficiently through higher investment, if the products are not essential and the resources can be more usefully employed elsewhere. Restraint may be necessary, at least temporarily, on the consumption of such products as vegetable oils, tea, the better grades of coffee, leather and a fairly wide range of manufactures. This will seldom involve an absolute reduction in consumption or even in *per capita* consumption; a slowing down in the rate of growth will normally suffice. Restraints on home demand will normally mean that prices are higher than they otherwise would have been (though not necessarily higher absolutely). This may result from higher excise duties or from the charging of higher prices by producers who have to sell abroad at a loss.

There is a natural reluctance to restrain consumption, and especially when the goods are produced in India. But the belief that such goods must always be cheap and plentiful reveals a strange asymmetry of thought towards imports and exports respectively. If, say, 90–95 per cent of the country's needs of an article are produced in India, and the remaining 5–10 per cent imported, there will normally be little hesitation in cutting the imports drastically to *save* foreign exchange and making do with rather smaller supplies, even if this means considerably higher prices and profit margins. It thus seems a little strange that there should be opposition to a moderate slowing down in the growth of consumption of goods produced in India that could be exported and *earn* foreign exchange, especially if this is done by excise taxes which accrue to the Government.

It must be remembered that restraints on consumption will be recouped several times over in terms of production of other goods, since the extra exports will make possible the import of vital bottleneck items. In general, the public must be convinced that, without such restraints, an adequate rate of development will be impossible and that that would be a much more serious matter.

4. *Adequate production for export*

The scope for restraining home demand is, however, limited, especially when the product meets a really essential need of the mass of the people or is a material, component or piece of equipment vital for the country's economic development. It is thus essential, particularly in these cases, that output of exportable goods is adequately expanded. It must not lag behind home demand, as has happened too often in the past. This means ensuring sufficient investment in the industries concerned, that they have adequate supplies of materials, fertilisers, etc., and that any other necessary measures are taken (for example, a modification of the legislation on cow-slaughter could increase supplies of hides and leather for export).

Since resources will remain scarce, and especially imported equipment and materials, an essential corollary is the need for severe limitation of investment in production that is not absolutely essential, and that will not yield substantial net earnings or savings of foreign exchange, and especially when continuing net foreign expenditure would be involved. Only in this way can room be found for the more vital export projects. This means that many other schemes, though desirable in themselves, will have to be postponed till conditions are more favourable, and especially when they would benefit only the higher income groups.

Care must also be taken in the allocation of investment resources *between* activities that can earn or save foreign exchange. The calculations involved are difficult. Profitability in a narrow financial sense is not a sufficient criterion since, among other things, the value to the nation of extra exports or import-substitutes is considerably greater than it appears to be at existing rates of exchange. It is certainly necessary to work out the initial foreign exchange cost of the investment, the continuing annual foreign exchange costs and the continuing annual earning or saving of foreign exchange. The *net* annual earning or saving of foreign exchange as a proportion of the initial cost will not yet, however, provide a satisfactory criterion for choosing between investments because the use of scarce domestic goods and services must also be allowed for.

Indirect effects must be taken into account as well. For instance, in deciding whether to buy additional aircraft abroad for use on internal services, credit must be taken for the extra foreign tourists who would come to the country (assuming that inadequate air transport within India is limiting their number), and not only for the fares they would pay to Indian Airlines Corporation but for their other expenditure in India as well. Though such calculations are difficult, they should be seriously attempted and perhaps done more carefully than hitherto. This might suggest ways in which a re-allocation of investment would assist the balance of payments. (For example, investment in more ships, which can recoup their foreign exchange cost in a fairly short time, might turn out to be better than investment at the margin in some other export or import-saving activities.)

5. *Making exports competitive*

Even if sufficient supplies are made available for export, they cannot be sold unless prices are competitive. Measures to reduce costs will take time to bear fruit. In the meantime, if India is to achieve the large and rapid expansion in exports that is necessary, it seems essential that a good many exports should be sold below the domestic price and some below cost of production. This will be necessary over a fairly wide range of manufactures and for a rather small number of primary commodities, sugar being an outstanding example.

To make the best use of the nation's resources, preference should normally be given to products requiring a smaller rather than a larger rate of subsidy. (On this criterion sugar looks a bad bet, at least as a continuing export in the long run unless costs can be very substantially reduced, either through a geographical redistribution of Indian production or in other ways. But in the shorter run India clearly cannot afford not to sell the substantial surpluses that have arisen.)

Direct or indirect export subsidies will arouse some antagonism abroad. The rules of G.A.T.T. are somewhat strict on this matter (and surprisingly more strict than on import restrictions) but India has reserved her position. Trouble may, however, arise with producers both in rival exporting countries and in the importing nations.

India can, however, make a good case for at least temporary subsidies. The urgent need for increased export earnings is apparent. It can also be reasonably claimed that the ' infant industry ' argument for protection of import-competing industries applies, *mutatis mutandis*, to infant export industries, of which there are many in India. Moreover, many Governments subsidise exports in various ways; and the sale by industrial firms of exports at prices lower than those charged at home is a very common phenomenon.

(With some commodities, that do not need a subsidy, stable prices are as important as low ones. When prices fluctuate so widely as, for example, those of jute goods, buyers abroad will switch to substitutes with more stable prices; and every sharp rise in price will encourage substitutions and economies which will not be wholly reversed when prices fall again. Measures to reduce fluctuations in such prices are thus necessary.)

6. *Investment in selling*

The selling of vast additional amounts of exports, especially of the new manufactures, is bound to be an expensive business, in terms both of rupees and, more particularly, of foreign currencies. Such expenditure must be regarded as essential investment designed to earn foreign exchange and must not be skimped any more than investment in, say, steel works to save foreign exchange. Expenditure of foreign currency, both public and private, that can properly be attributed to export promotion probably does not exceed a very few crores. Even a large proportionate increase, say a doubling, though apparently difficult to afford in present circumstances, would be small in relation to the extra exports it might yield.

More Government money will have to be spent on, for example, trade fairs and missions; on trade representatives abroad (who will have to supply much more detailed and expert market information than has hitherto been available, for use both by Government and by business); and perhaps on export credit guarantees (the terms must be fully competitive with those offered by competitors abroad and this may require Government subsidisation of the Export Risks Insurance Corporation).

Foreign exchange must also be granted quite liberally to business firms, including those not yet well established, and to Government agencies engaged in export trade, not only for travel abroad but also for advertising, for building up stocks abroad and for the other needs of marketing; some firms or industries may need offices, showrooms or even foreign subsidiaries. Nor can India afford not to grant credits as long as those offered by other exporting nations, even if this sometimes involves waiting several years for the foreign exchange; this will still be a well worth while investment.

7. *The role of the advanced nations*

The advanced, aid-giving nations can do much to help or to obstruct India's export drive. They must be convinced that, without a massive increase in exports, India can never achieve independence of foreign aid, while maintaining rapid growth, and at the same time repay the large loans she is receiving. The slogan at the moment must be ' aid *and* trade ' if it is ever to be ' trade *not* aid '. In particular, the advanced nations must be convinced of the need for much more competition from the new Indian manufactures, not only in third markets but even in their own home markets. If restrictions are imposed on goods produced with ' cheap ' or ' sweated ' labour, as with cotton textiles, India's chances of achieving the exports she needs will be considerably reduced.

Merely to refrain from imposing such restrictions will not, however, be enough. More positive action to *encourage* imports from India (and other under-developed countries) is required. The analogy of the Marshall Plan is relevant. The U.S., while giving massive aid to Europe, embarked in effect on an *import* drive to help sales of European goods to the U.S. (while tolerating severe discriminatory restrictions against her own exports to Europe). For example, U.S. officials abroad actively sought out European products that might be saleable in the U.S.; American tourists were allowed to bring back as much as $500 worth of goods purchased abroad without paying duty; local purchases by American military forces in Europe were encouraged in various ways. (These measures have now, quite rightly, been reversed, as Europe's balance of payments has become much stronger.) The advanced nations could also help by persuading firms with interests in factories in India to waive agreements limiting exports from these factories.

III. Exports of the Newer Manufactures

I cannot discuss here the measures required to promote exports of each individual item of India's trade, but it may be useful to explore in a little more detail the special case of the newer manufactures, which will have to play such a vital role in the expansion of India's exports. During the Third Plan their contribution, though important, may not be a major one, but it must be during the Fourth.

How competitive are they?

There are various reasons why a significant range of these newer industries seems likely to be capable of exporting at competitive prices and why the range is likely to widen steadily:

(*a*) With very high grade iron ore, India should be able to produce cheap steel, although at present the prices charged by Indian steel works seem to be higher than those charged by many foreign producers, at least for steel to be made into exports.

(*b*) Indian wages per worker are a very small fraction of wages in the main exporting countries of Western Europe and North America (and probably less than half of wages in Japan). Even if output per worker in manufacturing as a whole were a still smaller fraction, so that labour costs per unit of output were in general higher in India, one would expect to find a fair number of industries in which Indian labour costs were lower. For international comparisons show that the relationship between output per worker in one country and another usually varies widely from industry to industry, and one would thus expect to find industries in which India's lower output per worker was more than offset by her lower wages.

In fact, I have found quite a number of firms in which this is so and even some where output per worker appears to be higher than it is abroad, although allowance must sometimes be made for higher costs resulting from lower efficiency of labour that are not reflected in figures of output per man, for example, where tools are used up more quickly. The quality of some Indian products may also be lower than

TABLE III

Fair Ex-works Price as per cent of C.I.F. Import price, excluding duty, for 62 manufactures[1]

	No. of items	*Per cent of total*	*Per cent Cumulative*
% 60 and under % 70	1	2	2
70 ,, 80	7	11	13
80 ,, 90	8	13	26
90 ,, 100	7	11	37
100 ,, 110	5	8	45
110 ,, 120	7	11	56
120 ,, 130	6	10	66
130 ,, 140	5	8	74
140 ,, 150	3	5	79
150 ,, 200	8	13	92
200 and over	5	8	100
	62	100	

[1] See Table IV for details.

that of foreign goods but again I have found quite a number of cases where users of Indian products have no complaints on this score.

(*c*) The reports of the Tariff Commission suggest that, while the ratio between costs at home and abroad varies greatly, a significant proportion of India's industries may, in fact, be competitive. The ' fair ex-works price ' of Indian products was found to be lower than the c.i.f. price of imports, excluding duty, in more than one-third of sixty-two cases studied (see tables III and IV). Conclusions about individual products cannot be drawn without further study—for comparisons of this sort are fraught with many difficulties[1]—but the general picture shown may be correct, unless the list is seriously unrepresentative of industry generally. The 'fair ex-works price' refers, not to the most efficient undertakings in each industry, but to a representative firm, and allowance is made for a reasonable profit.

To get a fair picture of India's competitive position in third markets, allowance should, however, be made for the cost of transporting manufactures from Indian factories to overseas countries—perhaps 5–10 per cent of the ex-works price *on average*, including handling, insurance and miscellaneous charges. (To assess India's ability to sell to countries now exporting to her, it would be necessary to make a further allowance for the cost of transporting their exports to her.) If appropriate allowances could be made, it might show that India was competitive in only perhaps one-quarter or less of the products.

(*d*) A wide range of manufactured products (in addition to cotton and jute manufactures) is in fact already being exported, though usually in very small quantities. It is not difficult to draw up a list of around fifty such products, or groups of products. Some may admittedly, however, be sold at prices that do not cover costs, for example, to secure import licences for machinery under export incentive schemes, to fulfil undertakings to export entered into when the plant was licensed, or to relieve temporary shortages abroad when a foreign collaborator cannot meet the demand in full.

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[1] While most products where the Indian price is lower are exported, there are also some exports of a fair number of products where the Indian price is shown to be higher and sometimes substantially higher.

(*e*) India's manufacturing costs should progressively decline, and the quality of her products improve, as the scale of production is increased, as managements acquire greater experience, as labour is trained and as better equipment is installed. The process should be faster than it is in the advanced countries since the rise in scale of production should be more rapid in India, since the advanced nations have largely exploited the economies of mass production in many industries, and since India can benefit greatly merely by taking over techniques they are already using, while they must rely much more for further cost reductions on new technological discoveries.

The growth in India's relative advantage, or the decline in her relative disadvantage, will, however, be retarded by the need to rely more and more on materials, components and equipment produced in the country which, initially at least, may often be more expensive than the imported product. Much will depend, too, on the rate of increase of wages, but despondency on this score can be overdone. What figures are available suggest that, in the engineering industries for example, labour earnings have risen substantially less quickly than labour productivity over the past decade; if true, this compares favourably with the experience of many other countries.

For these various reasons, it seems likely that Indian industry is capable of competing in export markets over a significant range of products, and that the range will widen. Even where industries are not yet competitive, the margin of disadvantage is often not very large. India is thus more favourably placed than a good many under-developed countries where the great bulk of manufacturing industries is sometimes still hopelessly uncompetitive.

Promoting the new manufactured exports

The range of competitive industries does not yet seem wide enough, however, to make possible the rapid expansion of exports required, and to induce sufficient firms to enter foreign markets, even in a small way, early in the Third Plan, so that they can gain experience of marketing which will enable them to achieve the really massive expansion of exports that must come during the Fourth. Concentration on a narrow range of products will not be enough, especially as this would mean securing more substantial shares of markets for individual products and so increase the danger of protective reactions abroad.

In the U.S.A., which still relies substantially on exports of primary products, probably nearly half the manufacturing industries can produce more cheaply than their competitors abroad. In countries like the U.K. and Germany, which rely mainly on manufactured exports, the fraction is probably substantially higher. It would seem that, if India is to achieve the rapid expansion of exports she needs, something approaching one-half of her industries must now be made competitive, especially as her manufacturers will often have to sell below ruling prices to get an entry into new markets. Some measure of subsidy is thus necessary until costs have been sufficiently reduced.

In addition, even where Indian producers are competitive, the pull of the sellers' market at home, with its strong demand and good prices, seriously weakens any incentive to export. In countries like the U.K., Germany, Belgium, Sweden or Japan, where a substantial fraction of output is traditionally exported by many manufacturing industries, producers will continue to make efforts and sacrifices in the export market even when home demand is strong. But in India there is no such tradition of exporting manufactures on a large scale outside the cotton and jute industries. Powerful measures to make the home market relatively less attractive are thus necessary.

It may be that a change in the relative profitability of home and export sales by as much as would result from a devaluation of about 25 per cent is required, and that the measures taken should include direct and indirect export subsidies of more than half this amount. These guesses are based partly on evidence given above and in Tables III and IV, partly on general experience of the degree of devaluation required in the past by countries needing a large expansion of exports. A twisting of the relative cost and price structure of this order through *general* measures seems necessary to provide the background against which *specific* measures can be effectively operated to bribe, bully or cajole individual producers or industries, export houses, etc., to sell more abroad.

Such specific measures will also be essential, but it would be unwise to rely on them alone, if only because of the time required to put them into operation on a sufficient scale, since so many industries and firms are concerned. The administrative problems, too, are formidable and the dangers of abuse probably greater than with general measures. Moreover, while business men may be persuaded to export provided any financial sacrifice is not too great, they are much less easily persuaded, and much more likely to find ways of getting round a directive, if the sacrifice is substantial.

General measures may, it is true, give a few exporters more subsidy than they need; but they will normally be the ones with the greatest comparative advantage who should be encouraged most. In any case, any resulting inequities, and any demoralising effects of subsidies generally, would seem to be a much less serious matter than a failure to expand exports sufficiently.

The choice of general measures will depend on administrative and political considerations and on how far a particular method of, in effect, subsidising exports is likely to provoke unfavourable reactions abroad. Whatever methods are chosen, it is essential that, taken together, they give an incentive to export of the required magnitude. Five possible types of general measures may be mentioned (and others are conceivable) together with some illustrative orders of magnitude.

(i) Drawbacks of customs and excise duties on materials used are already given to some exporters (as are certain rebates on railway freights), but the field covered is limited and the procedure often complicated and prolonged; and while an exporter is waiting for refunds, he may be short of working capital. Drawbacks might be simplified, consolidated, applied to more products, and perhaps to materials contained in components bought by exporting firms. They might also be made more generous and to cover more taxes. I do not suppose, however, that the assistance to exports would much exceed, say, 5 per cent on average.

(ii) A difference of, say, 20 per cent between the prices of steel for the manufacture of home and export goods (obtained partly by raising the former prices, partly by lowering the latter) would reduce the relative costs of engineering products for export by around 5 per cent, assuming that steel accounts for about one-quarter of the cost on average. In some engineering industries the effect would, however, be smaller—it seems, for example, that iron and steel account for only about one-eighth of the cost of electric fans and bicycles and about one-sixteenth of the cost of sewing machines—and the effect would be negligible in most non-engineering industries. Similar schemes might thus be introduced for other materials.

(iii) Additional excise or purchase taxes on an appropriate range of manufactures would help to restrain the growth of consumption, release supplies for export and force manufacturers to seek out export markets. They would also tend to reduce the price to the manufacturer of sales in the home market and thus the gap which often exists between home and export prices; but a tax of, say, 10 per cent would not usually reduce the home price to the producer by as much as 10 per cent since part at least of the tax would be passed on to the consumer. Taxes on manufactures seem to be moderate and not very widespread, at least in comparison with a country like the United Kingdom.

(iv) Exporters of manufactures could be given a remission of tax on profits. Ideally one would like to reward only those making *additional* exports but the danger of collusion might rule this out. (For example, two exporters might agree that one would increase the exports made under his name while the other reduced his by an equal amount, and that the gain from tax remission would be shared between them.) Since, however, exports of the newer manufactures are at present small but should grow rapidly, tax remission on *all* such exports would come to more or less the same thing, and involve only a small loss to the revenue for some time to come. Any danger of overinvoicing could presumably be largely avoided if the tax-payer were given credit only for foreign exchange turned in to the authorities.

If, say, 20 per cent of export proceeds were allowed to be deducted from taxable income, this would be equivalent to an export subsidy of nearly 10 per cent. The loss of revenue (together with that on the drawbacks mentioned earlier) could be financed many times over by the indirect taxes proposed above or, alternatively, by a somewhat higher rate of tax on profits generally, so that the profit-earning class as a whole would not benefit while the general public was making sacrifices as a result of higher excise taxes and in other ways. (It should also be remembered that the additional exports resulting from the tax remission would make possible extra imports of scarce materials which would in turn allow an increase several times as great in production and incomes; and taxes on these might go far to offset the initial loss of revenue.)

Schemes of this type are in operation in some other countries, including Japan and Ireland. Ireland has been able to administer a scheme applying to *additional* exports of manufactures and, incidentally, nearly doubled her industrial exports between 1958 and 1960, although the tax relief cannot, of course, be given full credit.

(v) Exporters could be allowed, in effect, to retain a fraction of their foreign exchange earnings and use this to buy imports which could be sold at a substantial profit, as has been done with success in, for example, Pakistan. If any article, including a luxury, could be imported, this would, besides raising social problems, add to the import bill, which tax remission would not. Exporters might, of course, only be given import licences that were then taken away from other importers; but this would not be easy to administer and the extent of the effective subsidy would vary greatly from time to time. Measures of this sort cannot be ruled out but it might prove better to reserve them for specific incentive schemes, including those where, as at present, the exporter is allowed to import supplies for use in his own factory.

Against a background of general measures such as these, specific measures would have much more chance of success. Individual industries or firms might more easily be induced, for example, to export an agreed, and rising, fraction of their output as a condition for permission to buy vital components, etc. (It would hardly seem practicable to use a financial sanction since this would in effect be a tax and it would be difficult to define with sufficient precision the conditions under which it would be imposed.) In some industries a single firm might be selected to concentrate largely on export and in return receive preferential allocations of foreign exchange for machinery, materials, foreign travel, etc.; such a firm could achieve economies of scale in foreign marketing and concentrate on types and qualities demanded abroad. In some industries, levies on home sales might be necessary to finance export subsidies, despite the general measures; in others it would be sufficient for individual firms to finance any losses on exports by higher profits on home sales.

If, moreover, the general cost and price structure had been substantially shifted in favour of exports, expenditure on trade fairs and missions, more liberal allocation of foreign exchange to would-be exporters and all the other paraphernalia of an export drive would be likely to yield much higher returns.

Selecting the new manufactures

The proportion of India's total output of the newer manufactures that has to be exported in the Fifth Plan seems likely to be less than 10 per cent. But, since this ratio will not be uniform, some industries may have to export 20 per cent, 30 per cent or more of their output. These are substantial fractions and it is thus important to get some idea of what the industries are likely to be, so that provision can be made for them in the Third as well as in the Fourth Plans. A number of promising candidates could already be selected with some confidence and these should be given every facility and encouragement to expand, especially where rapidly growing supplies are vital for the domestic market as well, so that home demand cannot be significantly restrained.

Unfortunately, however, it is often hard to forecast an industry's export potential, certainly much more difficult than demand for the home market; for so much depends on developments abroad and it is very hard to tell which infant industries will mature most quickly into adults capable of exporting. A great deal of flexibility will thus have to be maintained.

Marketing the new manufactures

Providing capacity to export and making prices competitive will not be enough. The exports have to be sold, and getting into foreign markets for manufactures can be a slow, difficult and expensive business, quite different from that of selling primary products in highly organised world markets (although the marketing of some primary products admittedly requires a high degree of skill and experience). Markets for manufactures are imperfect. Success in selling depends not only on price—though this is very important —but on quality, attention to local needs and preferences, quick delivery, effective advertising, employment of the right agents, facilities for after-sales service, the provision of spare parts, etc.; and competitors will often fight hard to preserve their share of the market. Exporting manufactures is a tough and competitive business. It is quite a different matter from producing for a highly protected home market, often with few competitors.

It is thus necessary to start now an intensified export drive. Such a drive may well take five years to bear much fruit. This was, I believe, broadly the experience of Western Europe and Japan in their attempts to raise exports of manufactures to the U.S. after the war to help fill the dollar gap.

The export drives of most of these countries hardly began until, say, 1949 (previously too they mostly had few goods to export and their currencies were often over-valued until the 1949 devaluations). Many people were rather sceptical about the possibilities, just as some are sceptical in India today. ‘How,’ they asked, ‘can you possibly export large quantities of manufactures to the U.S. when her productivity is so high, when she always has the latest things and when her industry is so flexible? Moreover, whenever you start doing well, the American Government will impose protective measures or American industry will find other ways of driving you out of the market.’

But, despite these forebodings, European Governments embarked on export drives and European business men went to the U.S. to explore the market and begin selling. They made plenty of mistakes but they learned by experience. During the five years 1950–54 progress was slow and often frustrating, but the ground was being well prepared. And during the following five years—1955–59—the harvest was reaped. Exports of manufactures to the U.S. were trebled; and the success was achieved by a wide variety of industries. (It was not simply a matter of small cars, as is sometimes thought; these accounted for only about one-quarter of the increase.)

As I see it, the Third Plan period should correspond to 1950–54 and the Fourth Plan to 1955–59. Hand in hand with the development of capacity, and reduction of costs, during the Third Plan should go preparations for a massive expansion of export sales all over the world in the Fourth; and one of the essential requirements is for producers in many fields to start exporting *now*, if only in a small way. The ‘ infant industry ’ argument can be applied not only to exports as well as to import-replacement, but also to selling as well as to producing.

In deciding whether to grant licences to schemes involving the collaboration of foreign firms, it is important to remember the advantages that could accrue to India’s export trade from the use of their selling organisations abroad. Any attempt to impose restrictive agreements limiting the right to export from India would naturally have to be resisted. Where such agreements already exist and exports seem possible, foreign firms may be prepared to waive them if they are shown that, unless foreign exchange can be earned by exporting, it will be difficult to grant them import licences for components, machinery, etc.

IV. Import Economy

Until recently, there has been much more emphasis on import saving than on export promotion in the strategy of India’s economic development. This has quite rightly led to large investments in the production of goods that were previously imported and the process will continue; without it India’s development could not proceed very far. It is now necessary, however, to ensure that the imports required to maintain this rapidly growing production are forthcoming and this means far higher exports to pay for them.

The greater emphasis required on investment in exports must not be at the expense of import-saving, for both are needed in a big way; it is not a question of ‘ either/or ’. It must be at the expense of activities that are not essential and that would not help the balance of payments.

However successful the export drive, foreign exchange will remain scarce for many years and it must be husbanded with great care. Though this paper is more concerned with export promotion, it may be worth mentioning some ways in which import economies might be made.

I doubt, for example, whether imported equipment is always used as sparingly as it should be. There is often a good deal more flexibility than is sometimes thought in the extent to which capital may be substituted for labour, and *vice versa*, in the large number of processes of production, handling, etc., that takes place in a modern enterprise. Licensing authorities cannot possibly check every detail in a proposed investment and a private business naturally tends to choose the methods that are cheapest at ruling prices. But ruling prices substantially understate the scarcity and cost to the nation of imported equipment (and indeed of capital equipment generally, but that is a problem in itself).

An increase in taxes on such equipment even above the levels to which they were raised in the last Budget—which was a step in the right direction—would induce more economy and lead to some substitution of India's plentiful labour. Such taxes should also apply to equipment used by public enterprises; ideally they could be told to use high 'shadow' prices for equipment when choosing their methods of production but I am doubtful whether this would be effective in practice. These taxes might lead to higher prices for the finished product but any increase would usually be rather small. Where the product was exportable, a rather larger export subsidy could be given if necessary.

The planned increases of production could also be achieved with smaller imports of capital equipment if more industries worked double or even treble shifts. Table I illustrated the rather surprising lack of multiple shift working in India. It may even be less common than in an advanced country like the U.S., an extraordinary state of affairs in a country so short of capital as India. The marginal capital-output ratio could be greatly reduced by more multiple shift working, especially while it was being extended, but later, too, when it was fully in operation. It would also help to spread the electricity load throughout the twenty-four hours of the day and so alleviate the power shortage.

Single shift working may often appear more economical, for multiple shifts raise a number of problems, but the advantage may be more apparent than real, at least from a national point of view. It would probably pay some firms to introduce multiple shifts if the prices of capital equipment and power were brought nearer to their cost to the nation, say by a tax on equipment as suggested above, and if electricity charges for industry were made higher during the day than at night. Multiple shifts would be further encouraged if firms that work them were given, for example, preferential allocation of materials and higher income tax allowances for depreciation than at present. Shift working could be enforced by stricter policies towards the licensing of new capacity in industries until double or treble shift working was in operation, even at the risk of limiting competition.

V. WHY NOT TO DEVALUE

It may be argued that the measures proposed in this paper, and particularly the taxes on imports and subsidies to exports, are rather similar in their effect to devaluation and that this would be a much simpler and more straightforward alternative. I have no space to discuss this complicated matter in any detail but a few brief comments may be made.

The import taxes would apply to only a fraction of imports and the export subsidies to only a fraction of exports. Devaluation would have much more widespread effects. It may prove necessary at some later date, if detailed controls become quite unworkable and ineffective because the gains from evasion become so great. But this time has not yet arrived and it may never come. It may eventually prove possible to achieve a balance, at existing rates of exchange and without too many controls or special taxes and subsidies, when infant export and import-saving industries have grown up and when sufficient investment has been made in export and import-saving activities generally.

If this is so, there is a strong case against a drastic measure that would have inflationary tendencies, reduce confidence in the currency, weaken a powerful argument for cost reduction and be fraught with other dangers and uncertainties. It might well, moreover, actually worsen the balance of payments, at least in the short run, because the foreign exchange earnings from exports might well be reduced while the foreign exchange cost of imports, which are severely restricted, would not fall.

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TABLE IV

Fair Ex-works price as per cent of C.I.F. Import Price, excluding duty[1]
(Based on Reports of Tariff Commission)

		Year of Tariff Commission's Report
Under 70%	Cotton belting	1957
70% and under 80%	Diesel fuel injection equipment—pump—Kirloskar	1959
	Transformers 750 K.V.A.	1960
	Fluted rollers	1960
	Sewing machines	1954
	Oil pressure lamps	1957
	Plastic shirt buttons	1959
	Sodium bichromate	1958
80% and under 90%	Automobile leaf springs	1959
	Piston rings	1960
	Automobile hand tyre inflator (pump)	1960
	Wood screws	1960
	Machine screws, ¼ in. × 2 in.[2]	1959
	Aluminium circles	1960
	Phenol formaldehyde moulding powder[3]	1959
	Potassium bichromate	1958

		Year of Tariff Commissioner's Report
90% and under 100%	Hair belting	1959
	Aluminium sheets	1960
	Brass sheets	1959
	Bare copper conductors	1960
	Bleaching powder	1958
	Calcium lactate	1960
	Plastic bush coat buttons	1959
100% and under 110%	Electric motors (squirrel cage) 3 and 10 h.p.	1958
	A.C.S.R. conductors, 30/7/0.118 in.	1960
	Oleic acid	1959
	Teachest plywood	1960
	Pears in syrup	1957
110% and under 120%	Transformers, 3000 K.V.A.	1960
	Aluminium ingots	1960
	Copper sheets	1959
	A.C.S.R. conductors, 6/1/0.083 in.	1960
	Hydroquinone	1959
	Plastic pant buttons	1959
	Dry cells[4]	1953
120% and under 130%	Piston assembly (Fiat)	1960
	Electric motors (squirrel cage) 50 h.p.	1958
	Transformers, 25 K.V.A.	1960
	Automatic looms	1960
	Grinding wheels	1959
	Stearic acid	1959
130% and under 140%	Spinning ring frames	1960
	Copper tubes	1959
	Brass tubes	1959
	A.C.S.R. conductors, 7/0.1379 in.	1960
	Caustic soda	1958
140% and under 150%	Acid dyes	1954
	Commercial plywood	1960
	Raspberry jam	1957
150% and under 200%	Diesel fuel injection equipment—Nozzle holders Kirloskar	1959
	Automobile sparking plugs	1960
	Bicycles[5]	1960
	Machine screws, $\frac{3}{16}$ in. × $\frac{1}{2}$ in.[2]	1959
	Zinc sheets	1959
	Calcium Carbide	1958
	Direct dyes	1954
	Sheet glass	1960
200% and over	Ball bearings	1960
	Ball bearings adapter	1960
	Soda ash	1958
	Congo red dyes	1954
	Sulphur black dyes	1954

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[1] The ' fair ex-works price ' is a slightly smaller percentage of the landed cost, ex duty.

[2] Compared with imports from Japan. If a comparison is made with imports from Sweden, the fair ex-works price is less than 80% of the c.i.f. price for machine screws of $\frac{1}{4}$ in. × 2 in., and less than 110% for screws of $\frac{3}{16}$ in. × $\frac{1}{2}$ in.

[3] Exclusive of duty on phenol formaldehyde and hexamine.

[4] Compared with imports from Hong Kong. If comparison is made with imports from the U.S., the fair ex-works price is less than 70% of the c.i.f. price.

[5] Lowest Indian price compared with price of imports from Japan. British bicycles are more expensive.

STRIKES, REDUNDANCY AND THE DEMAND CYCLE IN THE MOTOR CAR INDUSTRY

By H. A. Turner *and* J. Bescoby

The purpose of this article is to examine the connection between the marked development of industrial unrest in the motor industry since the war and the fluctuations in its output. Enquiry shows that the increased incidence of strikes in this industry has been largely concentrated in a particular sector—factories engaged in the final assembly of cars (or factories which belong to firms primarily engaged in final assembly). In effect, these plants are those of the so-called ' Big Five ' manufacturers, as well as of a handful of smaller firms—Rover and Jaguar, for example—which for convenience may be called the ' Independents '.

There are, however, no official statistics of disputes for this particular sector of the vehicle industries. Indeed, although it is clear that the recent strike-wave is merely the climax of a movement that began at the end of the war, it is only two years since the whole ' motors and cycles ' group together has been distinguished in official strike-statistics. We were therefore obliged to compile our own statistics of disputes in car-assembly firms; our sources, and the inevitable problems of definition, are fully discussed in a paper published elsewhere[1] (which also analyses the detailed causes of these strikes and their distribution between individual firms and centres), and we do not propose to deal with these matters here.

The general picture is shown in Diagram I: the outstanding feature of post-war strike trends being their evident connection with production. For instance, the manufacturers' pre-war peak annual output of some 400,000 cars had been regained by 1948–9; by 1960, despite the recession of that year, this output had more than trebled. This increase was achieved with comparatively little expansion of the manual labour force. The diagram shows that generally speaking both the annual frequency of strikes and the ' loss of working days ' through disputes have risen with output—from which some might infer (though we do not) that the extent and bitterness of strikes has been simply a function of the strains of rapidly increasing productivity.

The main peculiarity of the car firms' strike-pattern, however, lies in the fluctuations it contains. The frequency of strikes has varied pretty directly with output: the number of stoppages, while rising generally over the whole period, seems to have become increasingly sensitive to recessions—falling (with something of a lag) in the 1951–52 slump, falling again in 1956, and apparently responding immediately to the recession of 1960 (which came too late in that year to reduce its total output). So far, this is in line with the historical experience of industry at large, where a tendency for the *number of strikes* to rise in booms has long been familiar; but

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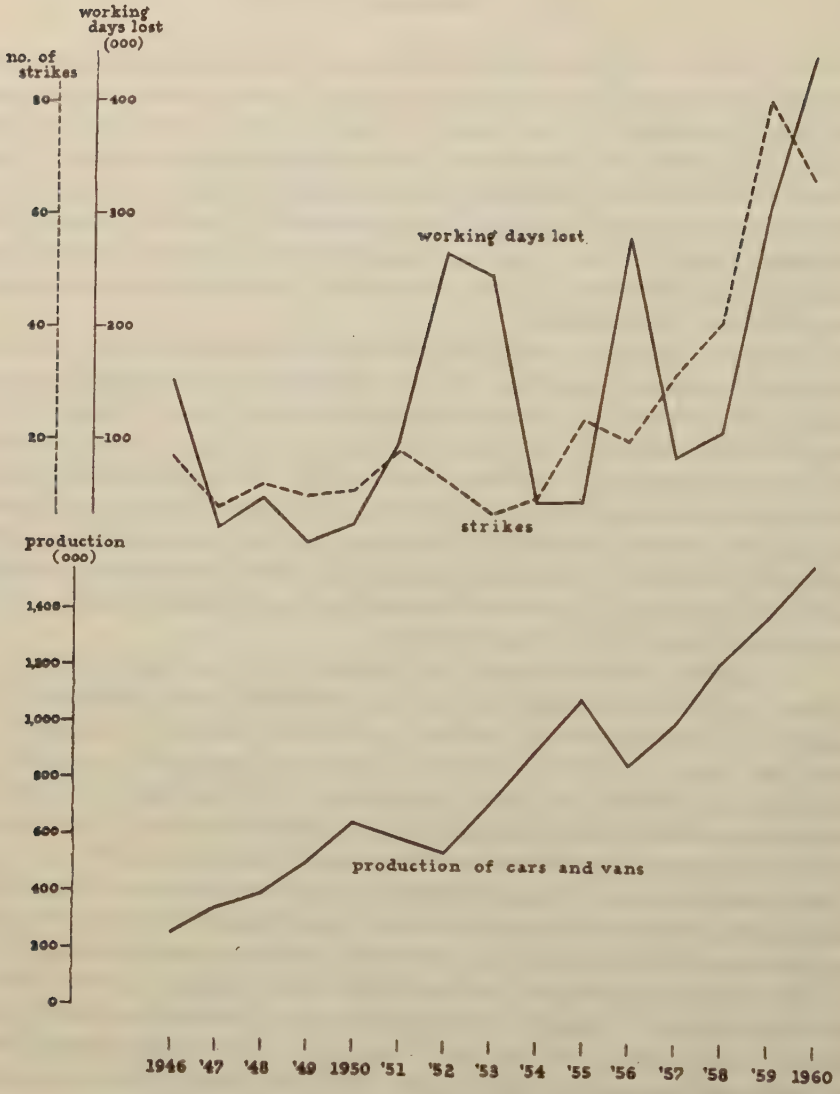
[1] See J. Bescoby and H. A. Turner, ' An Analysis of Post-War Labour Disputes in the British Car-Manufacturing Firms ' (*Manchester School*, May 1961), where help received is also acknowledged.

Diagram I: Strikes and output



no such systematic correspondence has been observed in industry generally between economic fluctuations and the *loss of working days* from disputes.[1] However, in car manufacturing during the 1950s this loss has varied almost inversely with the number of strikes—so that it has actually tended to reach a peak during the industry's recessions, just when the strike-frequency was falling off.

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[1] See K. G. J. C. Knowles, *Strikes: A Study in Industrial Conflict* (Blackwell, Oxford, 1952), p. 146 ff.

Nevertheless, this negative association between the number of strikes and the number of working days lost does bear one implication similar to that of the historical pattern for industry in general: namely, that stoppages tend to be frequent and small in booms while in slumps they become fewer but bigger or more protracted. Of this, the usual explanation is that, in a boom, workers are readier to strike spontaneously and employers are equally more willing to make concessions; but that in a slump, on the other hand, strikes only occur against what workers regard as attacks on their basic standards, so that for that very reason the strikes tend to be more massive and obdurate.

However, this sort of interpretation hardly explains the fluctuations in the strike trends of the car firms. Firstly, even the decline in frequency of strikes during recessions is not symptomatic of a general tendency but, as we shall show, affects only a distinguishable minority of car workers. Secondly, the loss of working days has not varied quite inversely with production: it has in fact risen, together with the number of strikes, in the later stages of the booms—but has continued to rise for a while after production (and, with production, the number of strikes) has turned down. Thirdly, it would hardly be possible to argue that car workers' strikes have been especially severe in recessions because of resistance to attacks on wage standards or other analogous conditions, as was true of many great disputes in the inter-war period. Out of more than 350 post-war strikes in the car firms we have not found a single one against a reduction in basic wage rates (even Standard Motors' proposal in 1960 to reduce disproportionate bonuses was abandoned after inconclusive discussions).

The post-war development of strikes against redundancy, however, suggests that workers' conceptions of their basic standards have been enlarged since pre-war days, and now include job-security: nearly a quarter of all the strikes, and rather more than a quarter of all the working time lost from disputes in the car firms since the war, are attributable to dismissals or to issues arising from a lack of employment. But this would hardly explain the particular severity of strikes in recessions, because in fact strikes on such issues have not been notably more numerous at these times.

The following table is a distribution of the strikes in the car industry according to their causes. We distinguish only four groups of causes because —difficulties of classification apart—little significance could be attached to annual variations within the framework of a more detailed breakdown. The numbers of strikes under each head do not, of course, give any indication of the contribution of the various issues to the total losses of working days, because strikes on different issues tend also to differ in severity: those on trade union questions (*e.g.* on the status of shop stewards) have been particularly big, while most wage disputes have been fairly small.

There have, clearly, been changes in the causation of car-firm strikes over time. Thus the relatively high incidence of strikes in 1946 was, to an important extent, due to a crop of disputes about trade union questions (the 'union shop', the recognition of particular organisations, etc.) which accompanied the car plants' readjustment to peacetime conditions. On the other hand

Post-War Strikes in Car Firms

Year		*Total number of strikes traced*[1]	*Number attributable*[2] *to:*			
			wages, wage-structure and work-loads	*redundancy, dismissals, etc.*	*trade union relationships ships, etc.*	*managerial arrangements, working conditions, etc.*
1946	...	17	5	3	7	2
1947	...	8	4	4	—	—
1948	...	12	4	2½	1½	4
1949	...	10	4	4	2	—
1950	...	11	5	2	2	2
1951	...	18	6	5½	3½	3
1952	...	13	6½	2½	3	1
1953	...	7	1	3	3	—
1954	...	10	5	½	3	1½
1955	...	24	13	5	5	1
1956	...	20	5	8	4	3
1957	...	32	14	8½	6½	3
1958	...	41	20½	10½	5	5
1959	...	80	53	8	12	7
1960[3]	...	66	35	17½	7	6½

[1] For sources, definitions, etc., see *Manchester School* article already quoted. Three national strikes in the engineering industry (which in fact affected certain car firms) are omitted.

[2] A stoppage involving two major issues is counted as half-a-strike under each of the revelant groups of causes.

[3] Provisional figures.

the very marked increase in the frequency of strikes during the late 1950s has been largely due to disputes about wages and related questions, which appear to have multiplied remarkably since the big car-firm mergers of 1952–53. While stoppages on other issues have all increased ' sympathetically ' to some extent, it is disputes about wages that have been responsible for most of the fluctuations in the frequency of strikes; and wage disputes seem to be the only variety of disturbance which has been markedly sensitive to the state of trade (as indicated by the production curve of Diagram I). Disputes arising from redundancy or related questions were the only kind to increase during the recession year of 1960; but they had also proliferated during the preceding boom.

What has happened, in effect, is that although strikes in support of straightforward wage demands have fallen off sharply during recessions, most other kinds of dispute—particularly those concerning employment—have become *individually* more severe. This is probably the clue to the special strike-pattern of the car firms. A major determinant of the severity of any strike is the extent of support it receives from the unions. The overwhelming majority of car workers' strikes have certainly started by being unofficial; but, if one takes the annual number of strikes as an indicator, the general militancy of car workers (apart from the minority referred to below) has been rising continuously since 1953. Thus, in the presence of an active shop stewards' movement and some degree of inter-union competition, union leaders have been under mounting pressure from their followers; and this has been reflected in a growing tendency of unions, if not to organise strikes, at least to reserve their disapproval, to pay strike benefit after the event, or to declare the strikes official once they had started.

This tendency was marked when the National Union of Vehicle Builders authorised the Austin strike of 1953 (which originated from a shop steward's dismissal arising out of a threatened redundancy, and resulted in the ' loss ' of over a quarter of a million working days); it became emphatic with the encouragement by the Transport and General Workers' Union of strike action against the British Motor Corporation for ' redundancy compensation ' in 1956. The development could have been graphically demonstrated if we had also plotted, in Diagram I—we omitted it in order to keep the diagram simple—the annual numbers of workers involved in disputes; for the number coming out on strike does, of course, depend a great deal on official trade union attitudes. Up to 1953, the curve of ' workers involved ' follows that of the frequency of strikes; but after 1953, when some strikes became bigger because they were officially or semi-officially supported, it follows that of working days lost.

Union leaders have to consider more than the immediate impulses of their rank and file. They are obviously concerned to maintain good negotiating relations with employers; they are fully aware of the increasingly delicate position of the British car industry in the foreign markets which have absorbed at least half the post-war increase in output; and they have become sensitive to a public opinion which they suspect of hostility. It can hardly be thought that they support strikes in recessions because they think them more likely to succeed at such times; indeed, the cuts in output required by market conditions have often been so sharp that the firms have been hard put to it to meet them by short-time alone—and yet firms have been reluctant to dismiss their workers, for fear of being unable to recoup their labour force later on. Thus, an official strike during a recession is likely to do least damage to union-employer relations—much of the output ' lost ' would not have been needed in any case; the strike can take place on issues and in circumstances most likely to attract public sympathy; and union members can take it that they will probably not only lose no work by striking but may also actually avoid the necessity of being dismissed. The official strike, in other words, becomes a form of ' work-spreading '.

This explanation of the distinctive pattern of strikes in the car industry becomes even more plausible when the pattern is examined in greater detail. There is, in fact, a very marked difference in the experience of major and minor car firms. We have been able to apportion the strikes in the industry fairly precisely between these two groups; and the result is depicted in Diagram II, which shows the trends, both in numbers of strikes and in working days lost, for each group separately. ' Major firms ' covers the Big Five, together with their subsidiaries and all the concerns that have merged with them since the war; ' minor firms ' represents the Independents, including not only concerns such as Jaguar but also some (such as Jowett) which have ceased car production in the course of the period.[1]

It is at once evident that the Independents' strike-frequency has been far

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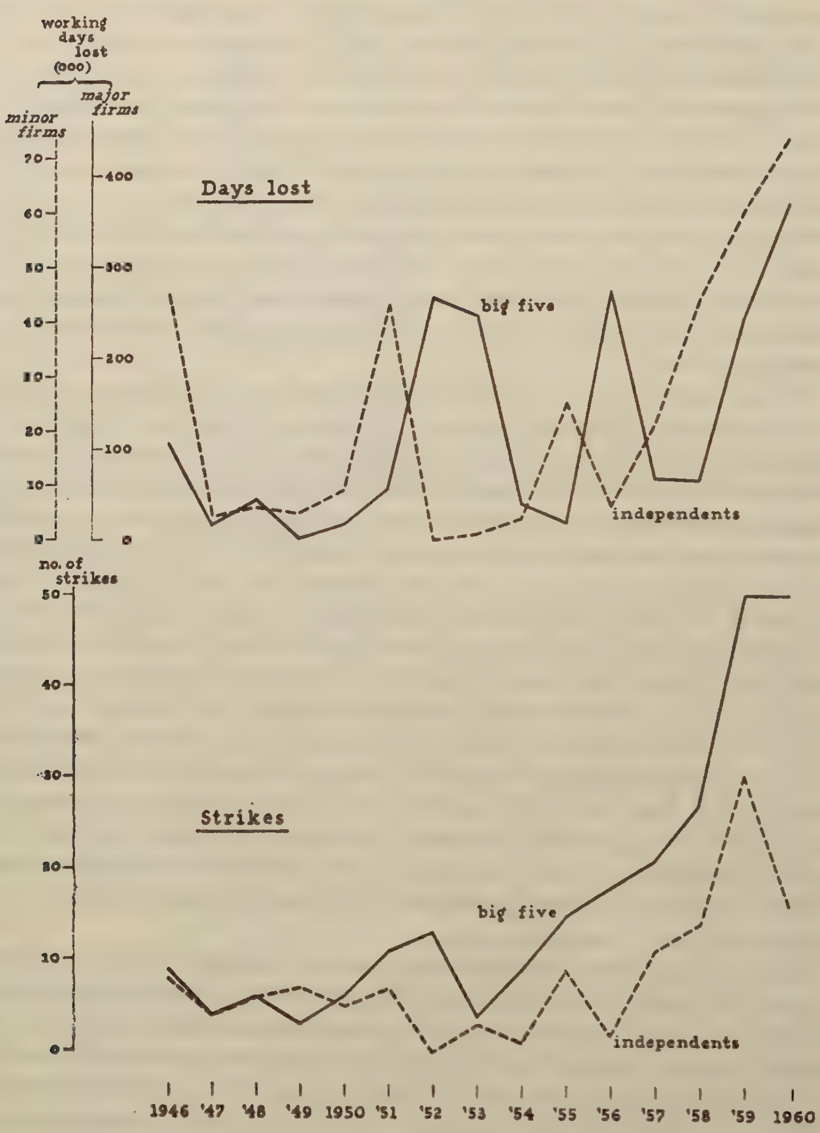
[1] On the writers' definitions, the Big Five have been responsible for over four-fifths of the employment in car-assembly firms.

Diagram II: Days lost and strikes in "major" and "minor" firms



the more sensitive to the state of trade: for them, for instance, strikes fell to zero during the recession of 1951–52. For the major firms, however, strikes did not fall off until 1953 (and this may have been a temporary effect of the mergers—for a while, nobody was quite sure whom to strike against). The frequency of strikes in minor firms again fell sharply in the slump of 1956; in the Big Five, it continued to rise uninterruptedly. In 1960 it once more declined abruptly for the Independents, although there was no actual fall for the major firms. This picture is no doubt a reflection of the marginal competitive position which several of the smaller firms have occupied: workers in them may well have been afraid that to strike in a recession would not postpone unemployment, but would accelerate it by pushing their firm over the competitive brink. This view seems to be confirmed by the experience of Standard and Daimler, which in the past few years have been the most insecurely ' marginal ' members of the Big Five and the Independents respectively (they were, of course, both eventually ' taken over '): over the same period, the readiness to strike in both these firms appears to have declined remarkably.

In contradiction to the general pattern, however (which tends to be dominated by the major firms' experience in this respect), the fluctuations of working days lost for the Independents follow those of their strike-frequency almost exactly. (The main exception is 1960, by which time some of their survivors no longer looked so marginal, and became involved in substantial disputes on dismissal or redundancy.) Indeed—as is suggested by Diagram II—in the minor firms there appears to be actually a tendency for strikes to get bigger at the top of a boom rather than at the bottom of a slump; and even for the Big Five, the frequency of strikes and the working days lost vary together up to 1953. It is thus the addition of something else to that underlying pattern which explains the fact that, after this date, working days lost reach their peaks in recessions for the industry as a whole. The ' addition ' is the large, more-or-less-official strike in non-marginal firms.

There is a historical analogy to all this in the experience of one of the most ' strike-prone ' of nineteenth-century industries: the implicit ' conspiracy to strike ' by which, it has been suggested, the expanding cotton trade overcame its incapacity to deal with periodic bouts of over-production. Any student of the development of the British car industry might well be struck by the resemblance of the rising output curve of this most typical of contemporary mass-production industries to that of its great historical predecessor. If the expansion plans of the major firms did not introduce—against a background of growing foreign competition and continuing structural and technical change—a new element of uncertainty into the prospects of car workers, the experience of 1960 suggested that their trade, too, is now subject to a regular cyclical trend.

To strike is perhaps not the most rational way to fill in a slump, but it is more interesting and sociable than some other forms of idleness and helps to keep workers from drifting away to other jobs. As this is being written, the Minister of Labour is discussing with the car workers' employers and unions how to reduce the incidence of labour disputes. The next year or two will be too early to judge of the success of these discussions since, as we have shown, the ' loss of working days ' from strikes is likely to fall off in any case as output recovers. But to the extent that they do succeed, the provision of other means to avoid or to meet redundancy will be the more urgent.

University of Manchester

MR. GLASSBOROW ON INVESTMENT CRITERIA[1]

By M. E. Beesley

Mr. Glassborow, in a contribution to the Bulletin symposium on the economics of roads,[2] describes the calculations made for the study of the London-Birmingham motorway, M.1, of which I was a co-author, as an estimate of 'social return' as opposed to a 'commercial or banker's assessment of return on capital normally used in connection with investments for business'. In particular he refers to the kind of commercial calculation made for railway investment and says, '... for investment schemes where passenger movement is largely concerned ... the social return will seldom be less than twice the commercial one'.[3] Because taxes paid by road users do not always reflect real costs, particularly of congestion on roads, and because the criteria for investment applied may be different for roads from those used for railways, he clearly fears that there is a danger of over-investment in roads relative to railways.[4] Quite apart from the question of applying comparable criteria, Mr. Glassborow also has some criticisms to offer of the particular methods used to evaluate savings in the M.1 case. He thinks that the savings are over-valued; as, when we wrote the original paper, we were more worried that we had under-valued them some comment on his points seems necessary.

Commercial Returns and Consumer Surpluses

As Mr. Foster pointed out in another article in the Bulletin,[5] the M.1 calculations really represent one of a vast number of possible surplus criteria, and actually might best be termed a very modest form of a consumer surplus measurement. The following table sets out the main categories of savings measured in the M.1 case. The justification for labelling this a 'consumer', rather than a 'social', surplus measurement is that the savings that concern non-users of the motorway are relatively small. The table gives the items used in calculating the numerator of the rate of return which was set against the initial capital cost of the M.1. The figures refer to 1955 traffic levels: these were adjusted for traffic growth. To non-users of the motorway there was attributed a figure of only £128,000 a year, representing their prospective reductions in costs, *plus* a share of the total 'leisure time' savings, put in the

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[1] Though I have had the benefit of discussion with Mr. D. J. Reynolds, formerly of the Road Research Laboratory, neither he nor the Laboratory bears any responsibility for the views expressed in this note.

[2] 'The Road Research Laboratory's Investment Criterion Examined', Bulletin, Vol. 22, No. 4, November 1960, p. 327.

[3] *Op. cit.*, p. 335.

[4] Although, as the foreword to the motorway study makes clear, the study itself had little or no influence on the decision to build the motorway. *The London–Birmingham Motorway, Traffic and Economics*, Road Research Technical Paper No. 46, H.M.S.O., 1960.

[5] 'Surplus Criteria for Investment', Bulletin, Vol. 22, No. 4, November 1960, pp. 337 ff.

TABLE I

London–Birmingham Motorway

Measured Savings, excluding Road Maintenance Costs, by Categories

	£'000 per annum	*% of vehicle cost changes*	*% of total savings*	
			from	*to*
Savings in costs of vehicles transferring to Motorway:				
Working time	624	69	45	36
Reduction in vehicle fleets ...	161			
Fuel consumption	84			
Other operating costs ...	200			
Costs of additional vehicle mileage	—307			
Reduction of costs to vehicles on old roads	128	12	8	6
Reduction of accidents	215	19	13	10
Total	1,105	100		
Generated traffic estimated ...	136		8	6
Leisure valued at 4s. to 8s. an hour	447 to 894		26	42
	1,688 to 2,135		100	100

Source: The London-Birmingham Motorway, Traffic and Economics, Road Research Laboratory Technical Paper No. 46, Table 32, second column.

original study at about 17 per cent.[1] Thus savings to non-users appear to amount to no more than 12 to 13 per cent. of total measured savings.[2] And, as we pointed out, certain prospective gains by consumers as a whole had to be left out of account. The important difference between a calculation of the M.1 type and that for the railways is thus between the use of *consumer* surplus and the use of commercial criteria; if this is so, then one would expect that a principal difference in the results of such calculations would be due to differences in assumptions about prices: the ' commercial ' calculation uses a set of prices reflecting a limited attempt to discriminate, whereas the consumer surplus calculation at least attempts to imagine a set of fully discriminating prices. The main question would then be what prevents the railways from applying fully their now quite sweeping powers to set the prices they wish. Mr. Glassborow's argument that an ' appropriate price structure . . . is fundamental to rational investment decisions ' for roads may be applied with equal force to the railways.

Mr. Foster suggests, and I agree, that to tackle the main problem—of the relative amounts of investment to be devoted to roads and to railways—one might ask that calculations similar to those used for the M.1 should be applied to the railways. If such a procedure were to be useful in indicating at least the order of magnitude of the amounts, some estimate of the returns available from a large number of possible projects would have to be made; possibly, if a satisfactory procedure could be found, by use of sampling. These estimates are not available; and the M.1 case is certainly not a representative road investment. As we pointed out, it is likely that it was not one of the 'best' possible road investments (compared, for example, with smaller projects elsewhere). One is on very insecure ground in inferring anything about the desirable allocation of investment between roads and railways on present evidence. Nevertheless, even confining ourselves to the evidence considered by Mr. Glassborow, I doubt whether the comparison between calculations for the M.1 type of roads and calculations of the commercial return on railway investment is really so unfavourable to the railways as Mr. Glassborow apparently fears. In assessing this Mr. Glassborow had the advantage of us in that he did not give details of the one calculation he recorded for the railways—a case of electrification of a suburban railway service. He concludes that 'depending on the view taken of likely traffic, the commercial return ranges between 7 and 10 per cent, but making the same assumptions about traffic the social return (of the M.1 type) would be some 30 per cent'.

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[1] *The London–Birmingham Motorway*, p. 61.

[2] Cost savings of 8 to 6 per cent of the total measured savings shown in Table I above, *plus* 17 per cent of the 'leisure time' saved, which itself varies between 26 and 42 per cent of the total saving (Table I).

In the first place, a considerable part of what we were forced to consider as consumer surplus in the M.1 case would form part of the internal adjustments in the case of the railways, and would thus feature in the calculation of a commercial return. This is due to the simple point that the railways own rolling stock which they use on their tracks, whereas road authorities do not. A calculation of the savings in the cost of operation of commercial vehicles in the M.1 case comes to a considerable part of the total vehicle cost changes attributed to M.1, as the following table shows:

TABLE II

Commercial Vehicle Cost Savings

	£'000 per annum
Commercial Vehicles transferring to Motorway:	
Working time of vehicles[1]	325.7
Reduction in fleets[2]	142.0
Fuel and other cost changes of commercial vehicles[3]	56.0
Total	523.7
Net savings in costs of all vehicles	890[4]

[1] *The London–Birmingham Motorway*, Table 25, second column.
[2] *Op. cit.*, Table 27.
[3] *Op. cit.*, Table 28.
[4] The sum of the first six items in the first column of Table I above.

The railways always count analogous savings as gains from invesment.

Second, Mr. Glassborow, in selecting for consideration a suburban service, is describing a case which must have, one imagines, a very high proportion of savings in leisure time, and he himself regards the valuation of leisure as debatable. On the other hand, the M.1 is notable for its high proportion of commercial vehicle work.

Third, an outstanding feature of investment in roads is the prospect of a large future growth in demand, which we were able to deal with only to a limited extent in the M.1 calculations. I am doubtful whether the railways can often claim the support from increasing demand that the roads in general can.

Last, a more general point should be made. It seems clear from the Evidence before the Select Committee on Nationalized Industries (July 1960) that it is the convention, when calculating the so-called ' commercial ' return on a railway project, to compare the expected financial position after the new investment with that which would obtain if existing assets were to be renewed like-with-like. The net new investment is calculated by deducting from total new investment a sum which, in effect, represents the present (discounted) value of renewals of like-with-like assets; the return comprises the annual value of the improvement in the financial position over that to be expected if only renewals were undertaken.[1]

In cases where the existing assets are employed at a loss that could be expected to continue were they replaced, the comparison yields a rate of return representing the *difference* between fairly obviously ' bad ' investments (replacement) and ' better ' ones. The ' commercial ' return will, therefore, often be inflated; and the size of the B.T.C.'s current total losses on railways suggests that most of the projects considered may come into this category. The B.T.C.'s justification for this is that it feels that it would in any event have the obligation to keep the railways going, a view which, of course, is not ' commercial '. The procedures that apparently are used in the detailed calculations for projects are in fact an uneasy compromise between considerations of commercial profitability and the B.T.C.'s interpretation of the wider social good.[2]

The relevance of the price system

Mr. Glassborow quite rightly points out that the calculation of this value of M.1 was made in the context of a price system for road use which is, to say the least, defective. He remarks,[3]

> ' while the present tax system continues, the incidence of road congestion cannot indicate where investment in road improvements is economically desirable. . . . Sensible changes should first be made to the road tax structure and when the consequent effects on road vehicle uses have become apparent, traffic studies and forecasts which assume that an appropriate price will be charged can be made.'

It is certainly, of course, the case that in present conditions gains from road investment cannot be unequivocally demonstrated. The conclusion Mr.

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[1] See Appendix 29 (Memorandum by the British Transport Commission) and answers to questions 1084 and 1690; *Report from the Select Committee on Nationalized Industries together with the Proceedings of the Committee, Minutes of Evidence and Appendices: British Railways.* House of Commons, July 11th, 1960.

[2] Clearly the use of a ' built-in ' comparison with like-with-like replacement has many interesting consequences for the choice of railway investments which cannot be pursued here.

[3] *Op. cit.*, pp. 330 and 335.

Glassborow draws, however, seems to be a counsel of both perfection and despair. I agree that it would be better to have a tax system which reflected congestion costs, and that prices charged for the use of roads should aid investment and not hinder it. In fact congestion in the sense of rising average costs to road users as flows increase will nearly always be present, optimum tax structures or not. But Mr. Glassborow, it would seem, would have us wait for a proper road tax structure before undertaking any road investment at all. Unfortunately, it is a reasonable guess that the existing tax system will change very slowly indeed. Meanwhile investment plans of some kind have to be carried out, for, presumably, zero net investment would involve great losses—though, from Mr. Glassborow's arguments, these cannot be rigorously proved either. Of course, one might argue that road investment should be directed as if the proper prices were being charged. This, however, would only compound the difficulties, already great, of making assessments of road benefits.

The best that can be hoped for are rough and ready adjustments to such calculations as can be made. Improvement in methods of calculation is greatly to be commended, but my guess is that if present evidence of road congestion were more influential than it now appears to be in deciding the allocation of road investment as a whole, the motorway programme would receive less emphasis, the order of priorities for building each stretch would be different, and there would be, in consequence, a considerable gain to the community. And the danger of a general over-investment on roads in towns is not yet great.

Suppose, however, road taxes *were* altered to reflect the real costs of road congestion. Would this, as Mr. Glassborow believes, reduce the value which, using our methods, would be attributed to the M.1 type of investment?[1] The answer to this depends in part on what precisely one means by ' taxing to take account of congestion ' and in part upon how far the relief of particular congestion spots is taken into the method of calculation for M.1. If by relief of congestion one simply means making users of vehicles pay for the costs they impose on other users where roads are congested, then taxing will mean that the aggregate costs of users will fall. If the tax is then given back to vehicle users as a whole, which would be quite consistent with the objective, a greater use of M.1 is possible, for vehicle users would be better off, and no congestion taxes would presumably be raised for the use of the M.1 for at least a considerable period of time.[2] If one has in mind raising taxes to reflect costs imposed by vehicle users on non-vehicle users, then the taxes will work in the opposite direction; no doubt both effects would be present in an optimal tax system, but the first effect is probably the more important. And it should not be forgotten that M.1 is a rural road, albeit a large one, and rural road users are at present overtaxed relative to others, as Mr. Munby has pointed out in another article in the BULLETIN.[1] On the other hand, the M.1 calculations also included sums representing the reduction of costs to vehicles on old roads near the motorway; a proper taxing system would help to reduce, but would not eliminate, these gains. But they are, as Table I showed, rather a small part of measured savings. I should, on balance, be surprised to find a reduction in the value of M.1 because of the imposition of congestion taxes.

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[1] For example: ' The volume of traffic on M.1 and the return by way of fuel duty would be lower if more were to be charged for other parts of the journey ', *op. cit.*, p. 333.

[2] This is of course one aspect of the argument that M.1 is too large an investment.

The Valuation of the Savings

Mr. Glassborow's main criticism of our computations was that the value of time savings was considerably exaggerated. The major source of savings is indeed time. The saving of time, we argued, in part enables resources to be saved and in part represents gains to people directly as more leisure time. Mr. Glassborow considers only the savings of people's time. In the case of the use of certain physical resources, for example vehicle fleets, the savings in time were, in our study, translated into estimates of vehicle costs avoided. We divided up time savings of persons into hours saved by those who were paid for what they did (called savings in working time) and the rest (called leisure time savings). Mr. Glassborow criticises our approach in two main ways: first that part of the working time must be divided up according to whether the people concerned are those whose ' work is driving ' (*viz.* the lorry drivers, etc.) and those who ' travel on business ' (of whom the best example might be commercial travellers). He feels that the latter savings should be regarded as additional leisure time, and, second, that leisure should be valued at less than the average wages or salaries, principally because these represent ' the reward not only for giving up leisure but also for doing work '.

As to the first argument, I am unable to agree to the relevance of the distinction. *Any* time saving by a man while doing the work he is paid for, whether he is a full-time traveller or only drives as part of his work, may result in additional leisure to him rather than an alternative commercial use, but we held it probable, as a first approximation, that there would be a reduction in the resources necessary to perform the existing amount of commerce (schedules would be adjusted to recognise better travelling conditions enabling lorry drivers *and* commercial travellers to make more calls, for example). There is thus no need to discriminate in this respect between the lorry driver and the commercial traveller on business. It is true, of course, that the valuation placed upon the time saving—average wages and salaries adjusted in various ways—is still a very imperfect indicator of the value of time saved, but that was a constraint of the data we had to accept.

On the second issue, I cannot agree that one must value leisure less for the reasons Mr. Glassborow gives. As far as this argument goes it seems clear that individuals do not value time as such, in the abstract, at all, and that it is only in relation to the various activities that time makes possible that it can acquire a subjective value. Income is paid to compensate people for giving up one set of activities for another. If one wishes to persuade a person to give up existing leisure activities one has to pay more—usually more than the average wage he earns. It is true, then, that increased opportunity for leisure because of a reduction in working time must be valued at less than the *marginal* wage; but there is no reason to suppose that it should be valued at less than the average (even if that average, as Mr. Glassborow points out, includes income tax).

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[1] ' The Roads as Economic Assets ', Vol. 22, No. 4, p. 286.

What we called ' leisure time ' savings occurred where no commercial activity was in question: users would find their existing leisure time expanded by using M.1. Now it is true that in a perfectly competitive world this would also affect choices between work and leisure and should in principle be measured at the margin between them. The connection in the real world seemed to us to be too tenuous to attempt such a measure. However, even within holiday times people will use a quicker facility and, for example in America, pay willingly for it. Time saved on leisure obviously in general has a positive value varying with the particular activities the person is engaged in; we suggested computing a range of four shillings to eight shillings an hour. This would represent tolls on the motorway of about ⅜d. to ¾d. a mile. Even though, as noted earlier, users of rural roads in general pay too much tax compared with other users, it seems to me that people would be prepared to pay this extra toll in order to use a facility like the motorway. In this, however, my guess is only as good as anyone else's. In sum, I do not think there is any reason to suppose that ' as a result of an over-valuation of time savings, the London–Birmingham motorway assessment considerably overstates the value to the community of this investment '. For other reasons there is an active possibility of an under-valuation principally because, first, amenities to drivers using the facility and not counted in the estimates are, I think, certain greatly to outweigh any disamenity, and second, as already argued, the long-run demand for facilities of this type, even given a proper pricing system for roads, is very favourable and was only partly brought into the calculations of the rate of return. But Mr. Glassborow has given a most useful warning about the value of the M.1 relative to other road investments, for it is highly probable that better returns could have been secured on the sums invested, both by saving on the M.1 itself and by investing elsewhere.

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A REJOINDER

By D. W. Glassborow

In writing this brief comment on Dr. Beesley's note, I would like to make clear at the outset that, in my view, the questions I raised in my original article are important and should not become simply the subject of a private argument between Dr. Beesley and myself. I would therefore not have felt it desirable to make this comment if Dr. Beesley's note had appeared to me to advance the discussion.

With one exception, it appears to me that Dr. Beesley has done very little more than restate the position expounded at greater length in the D.S.I.R. Paper. The exception is that I feel he has in his note misrepresented not only my motives in writing my original article (this is not of great importance) but also the views I expressed there. I would therefore ask anyone who is interested in the current Bulletin to refer back to my original paper when judging the validity of Dr. Beesley's criticisms. And also with more profit to re-read both Mr. Munby's introduction and keynote article in the same Bulletin.

The penultimate paragraph on page 328 of my article sets out my approach and is the simplest answer to his suggestion that I have approached the matter from a partisan railway viewpoint.

The expenditure of some £3,500 million on road investment would be of importance even if there were no other means of transport such as air, water, pipelines, railways or electricity grids. I will not, therefore, follow Dr. Beesley into the sterile fields of road/rail controversy into which he has begun to lead this discussion.

The remaining points I would now wish to make are few. Though it is not at once apparent from his note, Dr. Beesley admits, as Mr. Foster in his discussion of one of the major questions I posed clearly shows, that his consumers' surplus calculation is not the same as a commercial one. Dr. Beesley merely tries to suggest that the difference is not very great. Whether this is so is a question which requires much discussion and research and cannot be answered simply by reference to the D.S.I.R. Paper.

Concerning his argument that we cannot postpone road investment while waiting for a better price system for using roads, such a political view does not justify using the façade of a scientific calculation to conceal the fact that from an economic viewpoint road investment decisions are based on ' hunch '.

To me one of the most interesting questions is the proper valuation of time. This I would like to see discussed at more length. I do not find Dr. Beesley's arguments convincing or illuminating. He refers to tolls. What proportion of the toll roads in the United States are really profitable?

May I end by suggesting that Dr. Beesley's final remark that ' it is highly probable that better returns could have been secured on the sums invested both by saving on the M.1 itself and by investing elsewhere ', itself justifies more discussion and research. After all, not only have suggestions for additional capital expenditure on M.1 been made but also, a priori, one would expect M.1 to be, from an economic angle, about the best of the motorways.